Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat (CSAS)

Research Document 2023/079

Central and Arctic Region

Information to Support the Assessment of Northern Shrimp, *Pandalus borealis*, and Striped Shrimp, *Pandalus montagui*, in the Eastern and Western Assessment Zones, February 2017

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November 2023

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-68000-2 Cat. No. Fs70-5/2023-079E-PDF

Correct citation for this publication:

Walkusz, W., and Atchison, S. 2023. Information to Support the Assessment of Northern Shrimp, *Pandalus borealis*, and Striped Shrimp, *Pandalus montagui*, in the Eastern and Western Assessment Zones, February 2017. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/079. iv + 66 p.

Aussi disponible en français :

Walkusz, W., et Atchison, S. 2023. Information à l'appui de l'évaluation de la crevette nordique, Pandalus borealis*, et de la crevette ésope,* Pandalus montagui*, dans les zones d'évaluation Est et Ouest, février 2017. Secr. can. des avis sci. du MPO. Doc. de rech. 2023/079. iv + 67 p.*

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ABSTRACT

The status of the Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*P. montagui*) resources in the Eastern Assessment Zone (EAZ) and the Western Assessment Zone (WAZ) were assessed based on the results of fishery-independent surveys jointly conducted by Fisheries and Oceans Canada (DFO) and the Northern Shrimp Research Foundation (NSRF) and commercial catch information. Data for the EAZ assessment spanned the years 2006–2016. Results from individual survey areas within the EAZ are provided. Northern Shrimp in the EAZ were assessed to be within the Healthy Zone of the Precautionary Approach Framework with the fishable biomass in the last two years (2015 and 2016) being higher than the long term mean for the area. The potential exploitation rate for 2016/17, based on the TAC of 9,488 t, is approximately 14.5%. Striped Shrimp biomass in the EAZ has fluctuated considerably over the past six surveys, making interpretation of the time series challenging as no clear trend can be inferred. These fluctuations moved Striped Shrimp in the EAZ from a middle point of the Cautious Zone in 2015/16 into the Healthy Zone in 2016/17. Taking into consideration the large interannual biomass fluctuations, caution is advised when setting the TAC for the 2016/17 fishing season. The latest survey (2016) was the third consecutive survey since the time series restarted in the WAZ due to changes in the survey vessel, gear and timing, and a lack of standardization with the prior surveys. The potential exploitation rate indices are 15.9% and 19.3% for Northern Shrimp and Striped Shrimp, respectively, in the WAZ in 2016. These rates are above the target exploitation rate of 15%. While a statistically significant declining trend has not been detected, continuous declines over the last 3 years in the mean biomass for Striped Shrimp in the WAZ are cause for caution when setting the TAC. Precaution should be taken with the WAZ stocks until there is an adequate time series (i.e., at least 5 years of surveys) to develop reference points for the WAZ.

INTRODUCTION

Fisheries and Oceans Canada (DFO) Central and Arctic Region Resource Management (currently Ontario and Prairie) requested an assessment of the shrimp resources in the DFO management units Nunavut, Nunavik and Davis Strait (Figure 1). The shrimp resources were assessed within the Eastern Assessment Zone (EAZ) and Western Assessment Zone (WAZ) (Figure 2) based on four survey areas each with independently allocated stations (Figure 3).

The first survey efforts in the EAZ and WAZ took place in 2005. The survey methods and approaches changed considerably over time in the surveyed area. The historical background of the shrimp fishery and the survey efforts can be found in Siferd (2015).There is a relatively longer time series from the EAZ that was regularly surveyed by the DFO-NSRF (Northern Shrimp Research Foundation) survey (since 2009 with the same gear, modified Campelen trawl). The time series in the WAZ is only considered valid for the last three years (since 2014), when the series was reset; currently both areas are surveyed by the same vessel and the same gear (modified Campelen trawl) during the DFO-NSRF annual survey.

This document presents the results of research surveys conducted in the EAZ and WAZ through the 2016 DFO-NSRF survey. These results are compared to the 2015 DFO-NSRF survey in order to provide perspective of change. Fisheries data and fisheries-independent research survey results are the basis of the stock assessment of Northern and Striped shrimps in the EAZ and WAZ. The assessment follows the framework developed for shrimp stock in Nunavut and Newfoundland (i.e., SFA 4-6 [DFO 2007a]) where possible. The EAZ and WAZ were last assessed in 2015 (DFO 2015).

MATERIALS AND METHODS

SURVEY DESIGN AND PRACTICES

There are four survey areas within the boundaries of the EAZ and WAZ (Figure 3): SFA 2EX and RISA (East and West) in the EAZ and SFA 3 in the WAZ. The historical background pertinent to the establishing of the survey areas can be found in Siferd (2015).

EAZ Survey Areas

Both survey areas in the EAZ cover depths between 100 and 750 m. These depths are divided into the following depth strata: 100–200, 200–300, 300–400, 400–500, and 500–750 m. The 200-300 m stratum was removed from the SFA 2EX survey because the area contains untrawlable bottom. Also, unsuccessful fishing attempts in RISA prompted the removal of the 100–200 m strata and exclusion of a number of untrawlable locations. Currently the SFA 2EX covers a total area of 99,117 km^2 while RISA has a total area of 21,900 km^2.

Sampling locations within the depth strata are allocated in accordance with Doubleday's (1981) method. A detailed description of the development and revisions of the stratification scheme can be found in Siferd (2015). In short, the sampling locations are proportionally allocated to the size of the stratum area with a minimum of two sets per stratum regardless of its size.

Over the years, both the SFA 2EX and RISA surveys were conducted annually but with different vessels. These included the f/v Cape Ballard until 2011, Aqviq in 2012 and 2013, Kinguk in 2014, Katsheshuk II in 2015, and the Aqviq again in 2016. Considering the strong similarities in specification among these sampling platforms it has been concluded that conversion factors are not required to continue with a comparable time series (S. Walsh, DFO Emeritus, pers. comm.).

Similarly to previous years, sampling in 2016 was performed with a modified Campelen trawl (Siferd and Legge 2014). The trawl was equipped with 21'' footgear, as opposed to the standard 14'', with the rest of the specification remaining identical to the standard Campelen trawl.

Trawl monitoring was performed with a Marport® MBAR acoustic receiver coupled with Marport spread sensors to measure both the door and wing spread. A Furuno® trawl eye mounted on the headline was also used to visually observe trawl touchdown and therefore start/end of tows. The bottom time was calculated based on the Marport recordings of the Furuno trawl eye. Sampling onboard was conducted on a 24 hour basis.

The swept area during each tow was calculated as the product of vessel speed, bottom time and wing spread. Vessel speed was derived as the average of all speeds from GPS GPRMC strings recorded by the Marport system over the duration of the tow. Wing spread was determined through direct measurements from the wing sensors. In cases when direct measurements of wing spread were not available, a conversion from door spread through a formula derived from a comparison of door spread to wing spread over tows where both measures were present was used. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from the Marport recordings of the Furuno trawl eye.

Water temperature and salinity were recorded with a trawl mounted Seabird 19plus CTD. Mean bottom temperature and salinity were considered the averages of all measurements taken between the start and end of a tow while the trawl was on the bottom.

WAZ Survey Area

The SFA3 survey area has a total area of 58,279 km^2. It covers depths of 100 to 1,000 m and is divided into depth strata of 100–200, 200–300, 300–400, 400–500, 500–750 and 750–1,000 m. The bathymetry of the WAZ is such that natural strata were produced and no further subdivision of the contours was made. Since 2014, the WAZ has been surveyed annually.

Between 2014 and 2016, the WAZ was surveyed in conjunction with the DFO-NSRF survey of the EAZ. The stratification scheme developed for previous DFO surveys was used. However, during the 2014 survey the deepest, 750–1000 m, stratum could not have been fished, requiring that it be dropped in this and future surveys of the area. Sample allocation remained the same as earlier DFO surveys; buffered random sampling and standard DFO survey procedures were applied. Three extra sites were selected to act as alternates as required by the DFO-NSRF survey protocols.

In the WAZ, sampling stations within a stratum were allocated in proportion to stratum area, but with a two set minimum regardless of stratum size. All possible sampling sites within a survey stratum, based on a 3 x 3 km grid overlaying an equal-area projection of the area, were assigned to individual strata. A program developed by the Greenland Institute of Natural Resources (GINR) for buffered random sampling (Kingsley et al. 2004) was used to select sampling stations within each stratum of the study area.

Similarly to the EAZ, WAZ sampling in 2016 was performed with a modified Campelen trawl (Siferd and Legge 2014). The trawl was equipped with 21'' footgear, as oppose to the standard 14'', while the rest of the specification was identical to the standard Campelen trawl. Standard sampling procedures are to maintain a speed of 2.6 knots for 15 minutes for all tows. However, any tow with a duration greater than or equal to 10 minutes was considered successful providing the integrity of the equipment and catch remained intact. Sampling was conducted on a 24 hour basis.

As in the EAZ, swept area during each tow in WAZ was calculated as the product of vessel speed, bottom time and wing spread. Vessel speed was derived as the average of all speeds from GPS GPRMC strings recorded by the Marport system over the duration of the tow. Wing spread was determined through direct measurement from the wing mounted sensors. When direct measurements of wing spread were not available a conversion from door spread through a formula derived from a comparison of door spread to wing spread over tows where both measures were present, was used. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from the Marport recordings of the Furuno trawl eye.

Water temperature and salinity were recorded with a trawl-mounted Seabird 19plus CTD. Mean bottom temperature and salinity were considered the averages of all measurements taken between the start and end of a tow while the trawl was on the bottom.

CATCH PROCESSING

In all survey areas the catch was processed in the same manner aboard the vessel. From the catch, a random shrimp sample containing up to approximately 300 individuals was sorted to species. Northern Shrimp and Striped Shrimp were further divided into male, transitional, primiparous, multiparous or ovigerous stages based on characteristics according to Rasmussen (1953), Allen (1959) and McCrary (1971). These stages were further divided into batches by disease condition, carapace condition and whether head roe was present. Each batch was weighed to the nearest 0.0001 kg. The oblique carapace length (CL) of all Northern Shrimp and Striped Shrimp individuals within each batch was measured using digital calipers and electronically recorded to the nearest 0.01 mm.

BIOMASS ESTIMATION

Three categories of biomass (total, fishable and female spawning stock) for both species of shrimp in each survey area were calculated from observed survey catches. Fishable biomass is considered to be all females and all males with carapace length (CL) greater than 17 mm.

Female spawning stock biomass (SSB) represents all females present in the catch.

Regardless of the type of biomass, the calculation was performed the same way.

Catch Weight is the weight of the total catch of all species during a tow.

Catch Subsample Weight is the weight of a subsample taken from the total catch prior to any sorting.

Catch Subsample Ratio is the proportion of the total catch that was subsampled, i.e.:

$$Catch\ Subsample\ Ratio\ = \frac{Catch\ Subsample\ Weight}{Catch\ Weight}$$

Shrimp Sample Weight is the combined weight of all shrimp species in the subsample taken from the total catch (*Catch Subsample Weight*).

Shrimp Subsample Weight is the weight of a shrimp subsample taken from the shrimp sample weight.

Shrimp Subsample Ratio is the proportion of the shrimp catch in the subsample that was further subsampled before being sorted to species, i.e.:

$$Shrimp\ Subsample\ Ratio\ = \frac{Shrimp\ Subsample\ Weight}{Shrimp\ Sample\ Weight}$$

Shrimp Subsample Species Weight$_i$ is the combined weight of all specimens of shrimp species *i* in the shrimp subsample.

Shrimp Species Subsample Weight$_i$ is the weight of shrimp species *i* in the shrimp subsample extrapolated to the subsample taken from the total catch, i.e.:

$$Shrimp\ Species\ Subsample\ Weight_i = \frac{Shrimp\ Subsample\ Species\ Weight_i}{Shrimp\ Subsample\ Ratio}$$

Shrimp Species Weight$_i$ is the combined weight of all specimens of shrimp species *i* extrapolated to the total catch, i.e.:

$$Shrimp\ Species\ Weight_i = \frac{Shrimp\ Species\ Subsample\ Weight_i}{Subsample\ Ratio}$$

Shrimp Species Biomass of a particular shrimp species and biomass type caught at a sampling station in kilograms per square kilometer was calculated as:

$$Shrimp\ Species\ Biomass_{ij} = \frac{Shrimp\ Species\ Weight_i}{Swept\ Area}$$

where:

$_i$ – is a shrimp species,

$_j$ – is a biomass type,

Upper and lower confidence intervals (CI) were estimated by resampling statistics (Bruce et al. 2000). CIs were calculated by resampling from the observed catch with replacement to produce a biomass estimate for the survey area as described above. A set of 15,000 estimates was produced from additional runs based on a new sampling of the observed catch with replacement, then sorted in ascending order. Estimates at the 2.5 and 97.5 percentiles of all runs were considered the 95% CI for the biomass estimates.

PRECAUTIONARY APPROACH FRAMEWORK

Shrimp in the EAZ are assessed within a Precautionary Approach Framework (DFO 2007b). The Upper Stock and Limit Reference Points are 80% and 30% of the geometric mean of female spawning stock biomass.

Currently, there is no Precautionary Approach Framework in the WAZ.

TEMPERATURE

Contour plots of bottom temperature were produced by kriging mean bottom temperature data collected at each station using Surfer® Ver. 10 (Golden Software 2011).

RESULTS AND DISCUSSION

BOTTOM TEMPERATURE

There was a relatively strong increase in the area-weighted mean bottom temperature in the EAZ from 2009 to 2010 (Figure 4a and 4b). Since then the EAZ temperature has been declining each year, with a slight increase in 2015 followed by a decrease in 2016. This fluctuation, however, was relatively moderate, thus the temperature is still at levels similar to those seen prior to 2010. With its larger area, the EAZ index has been closely following, until the last survey, the pattern observed in the SFA 2EX index (Figure 4a). In 2016 a discrepancy between SFA 2EX and the EAZ trends was observed; the SFA 2EX temperature slightly increased, while that in EAZ recorded a slight decrease. In RISA, RISA-E has been 1.5 °C warmer than RISA-W while showing similar changes over the time series (Figure 4b). The temperature increase in 2010/2011 was greater in RISA-W but the decrease after 2011 was also greater.

Other than survey timing, the change in survey in the WAZ should have no effect on the time series of mean bottom temperatures. It would appear that the WAZ underwent a similar pattern of temperature change as seen in the EAZ but the biennial sampling may mask other changes in non-survey years (Figure 4c). In 2016, for the first time in the survey history, the average temperature in the WAZ was in the sub-zero range (-0.4 °C), approximately 1.5 °C colder than RISA-W and nearly 3 °C colder than RISA-E.

Temperature and salinity variability in Hudson Strait (WAZ) is strongly influenced by the major currents that flow within the Strait; these are a cold outflow from the Arctic that follows the southern coast and a relatively warm inflow from the Atlantic that propagates in the central/northern part of Hudson Strait (Straneo and Saucier 2008).

EASTERN ASSESSMENT ZONE

Survey Area Results

In 2015, the survey was conducted aboard the fishing vessel Katsheshuk II. The WAZ was surveyed first (28 August–3 September), followed by RISA (3–9 September), and finally SFA2EX (10–21 September). All 121 stations were sampled in SFA2EX, while 65 of 72 and 59 of 64 were sampled in the WAZ and EAZ, respectively.

In 2016, the survey was conducted from the fishing vessel Aqviq and took place slightly earlier than in 2015; the WAZ was surveyed first (4 August 11), followed by the RISA (12–20 August), and finally SFA2EX (20–31 August). Again, all 121 stations were sampled in SFAEX2, while 55 of 60 locations were surveyed in RISA and 67 of 69 in the WAZ.

SFA2EX *P. borealis* Biomass and Distribution

In 2016, the distribution of *P. borealis* catch (Figure 5 and 6) retained a similar pattern to that observed in previous surveys (DFO 2014, 2015). The main biomass concentrations were found in a relatively continuous band within the 300–400 m strata. The 100–200 m and 500–750 m strata contributed very little to the overall survey area biomass. This can be partially attributed to the Northern Shrimp ecological (thermal) optimum. The main concentration of *P. borealis* occurred in water of 1 to 2 °C in 2015 (Figure 7), however, in 2016 there appears to be more biomass in the waters with a temperature between 1 to 3 °C (Figure 8).

Total, fishable and female SSB indices appear fairly stable from 2007 to 2012, showing non-significant declines in mean biomass over the period of 2013–14 and non-significant increases in the last two years (2015 and 2016); currently no clear biomass trends have been observed (Figure 9).

SFA2EX *P. montagui* Biomass and Distribution

In 2015 and 2016, *P. montagui* was practically absent in SFA 2EX with only a few small catches taken in the southwest part of the survey area (Figure 10 and 11), a pattern consistent with previous surveys. The species is mostly found in the inshore 200–400 m depth strata. Generally, *P. montagui* are found in waters of -1 to 1 °C with larger catches coming from water 0 to 1 °C (Figures 12 and 13).

With the exception of 2009, total, fishable and female SSB biomass indices for *P. montagui* have been consistently low (< 2000 t; Figure 14).

RISA *P. borealis* Biomass and Distribution

In both 2015 and 2016 the largest catches of *P. borealis* came from the western side of RISA-E near Resolution Island in (Figures 15 and 16). As a consequence, the majority of the RISA *P. borealis* biomass came from RISA-E (Figure 17) with a smaller contribution from RISA-W (Figure 18). Biomass in RISA-E showed relatively large fluctuations over the time series with an increase in 2015 and decrease in 2016. RISA-W displayed a somewhat opposite trend with a biomass increase in 2013 and a declining trajectory since then (Figure 18). Most of the *P. borealis* in RISA are found in water with a temperature between 1 and 4 °C with the largest sets coming from waters of 2 to 3 °C (Figures 7 and 8).

RISA *P. montagui* Biomass and Distribution

In both 2015 and 2016 the largest catches of *P. montagui* in RISA-W were found west of the Button Islands and Resolution Island in (Figures 19 and 20); this pattern was consistent with previous surveys. In RISA-W, *P. montagui* are predominantly found in the shallower 200–300 m strata; however, in 2016 a few locations in the 400–500 m strata had relatively high catches.

Pandalus montagui biomass has been trending downward in RISA-E from 2008–2013 but showed a slight increase in 2014, a decline in 2015, and finally a larger increase in 2016 (Figure 21). In RISA-W, *P. montagui* biomass was stable and varied without trend from 2008 until the 2012 survey, when it sharply increased after which the biomass fluctuated around the historic mean (Figure 22). One of the explanations for such fluctuations would be the movement of shrimp biomass into and out of RISA-W.

Assessment of the EAZ

Eastern Assessment Zone – *P. borealis*

There are no apparent trends in the total, fishable and female SSB indices of *P. borealis* in the EAZ as these indices have fluctuated around their long-term means from 2008–2016 (Figure 23 and Table 1). The total and fishable biomasses fluctuated around the long term means of 66,628 t and 64,954 t, respectively. The 2016 estimate of fishable biomass was 65,570 t. Similarly to the two above mentioned indices, female SSB fluctuated around its long-term mean of 40,125 t, with a notable increase in biomass recorded in 2015. Female SSB in 2016 was estimated to be 34,827 t.

The sex ratio in the EAZ *P. borealis* population was examined (Figure 24). Given that, in most cases, the ratio of males to females in catches is skewed towards females, it seems natural that males are relatively less visible in the frequency curves (Figure 25). While there are differences in the sex ratio in some years, no overall trend is apparent in the time series.

Commercial fishing in the EAZ began in the late 1970s in the northeast part of SFA2EX. In 1989 a TAC of 3,500 t was introduced in that area for the very first time (Table 2, Figure 26). The TAC has been increased over the years to reach 9,488 t in 2016. Initially the catches of *P. borealis* in the EAZ were sparse. They started increasing in 1996 and reached a maximum in 2011/12 (7,423 t). In 2016/17 the total catch was 5,612 t (as of February 2, 2017). The majority of the EAZ catch is taken from the vicinity of the Resolution Island.

Dividing the reported catch by the fishable biomass produces an exploitation rate for the zone (Figure 27). There are two types of exploitation rates, reported and potential, which represent the ‘real’ amount of the total catch taken and the rate that will result if all of the TAC is taken. The reported exploitation rate has varied without trend around with a mean of 9.3% from 2008/09 onward (Figure 27a) and was slightly below the long term mean in 2016/17. If the entire *P. borealis* TAC in the EAZ had been taken, it would have resulted in a higher mean exploitation rate of about 14.3% over the same period (Figure 27b). The potential exploitation rate for 2016/17 was 14.5%.

The composition of the catch in the EAZ has been predominantly female from 2005/06 to 2014/15 (Figure 28). For fishing seasons 2010/11 through 2012/13, however, the composition was closer to equal proportions of males and females. In 2016/17 there were more males in the stock. Size ranges of shrimp caught over the years appear to be similar.

The EAZ *P. borealis* resource remains within the Healthy Zone of the PA Framework (Figure 29). The current TAC equates to a potential exploitation rate of about 14.5%, which is well below the maximum removal reference of 20% for the Healthy Zone.

Eastern Assessment Zone – *P. montagui*

Within the EAZ, RISA-W is the greatest contributor to the overall *P. montagui* resource. Any significant changes in the resource amounts in the RISA-W are mirrored in the fluctuations in the overall EAZ biomass indices (Figure 30, Table 3). Over the last 6 years the biomass indices have shown considerable inter-annual variation, suggesting the environment is highly dynamic. This situation makes the interpretation of the time series difficult and therefore the status of the stock remains uncertain.

It is important to note that the survey design used herein is virtually same as what is used in other Shrimp Fishing Areas in Canada and is deemed appropriate for this type of assessment. Thus, one should not suspect the survey design to be the cause of the observed fluctuations but rather other drivers need to be sought.

Fishing around Resolution Island (industry reports; W. Walkusz, DFO, pers. comm.), as well as within other highly dynamic areas (Drinkwater 1986, Hudon 1990), is known to be challenging from the catchability standpoint. The interplay of currents, tides and wind generated waves creates an environment where efficient and yet meaningful survey results are hard to achieve. One solution to the tide problem is sampling the RISA during the neap tide to minimize the impact. This, however, only helps with some sampling stations as sampling takes place around the clock, which means some fishing occurs with very strong currents. The effect of these variable sampling conditions has not been quantified and their impact on the overall assessment remains unknown.

Among other potential plausible explanations for the highly variable catches is that regional oceanographic dynamics could influence the distributional movements of the resource. With our one time a year approach (snapshot type of sampling) any seasonal changes in the distribution are hard to observe.

In most years there appear to be more females in the *P. montagui* population than males, however, in some years the prevalence of males is striking (Figure 31). This might indicate that the transition of males into females is not an annual process but could be an irregular one. At this point, we cannot be certain whether these results are due to sampling design (e.g., specific timing) or whether the pattern reflects the life history characteristic in the EAZ.

The relative abundance (proportion) of males and females in the EAZ *P. montagui* population shows a healthy sex ratio (Figure 32). While in the past the females/males ratio varied between the years, sometimes extremely, in 2016 it seemed to be close to par.

The fishery in the EAZ began in the late ‘70s with an initial quota for *P. montagui* of 100 t (Figure 33, Table 4). The quota increased over the years; however, the total catches rarely matched the available quota. The maximum catches were observed between 1999 and 2001; after that period catches have declined. The majority of the *P. montagui* quota is taken as by-catch during the directed *P. borealis* fishery, thus it is believed that the fishing fleet learned how to achieve cleaner catches (Siferd 2015). Also, changes in jurisdictional boundaries implemented in 1999 played a role in the pattern of observed catches (Siferd 2015).

Comparing the *P. montagui* catch in the EAZ to its fishable biomass produced a reported exploitation rate with a long term mean of 6.8% from 2008/09 to 2016/17 (Figure 34a). The potential exploitation rate, based on the summation of all quotas in the zone, has a much higher long term mean of 39.0% over the same time period (Figure 34b). The exploitation rate index is strongly affected by the fluctuations observed in the fishable biomass over the past six years. Currently, in 2016/17 the reported exploitation rate index is very low at 1.5% and the potential exploitation rate, based on the EAZ TAC, is about 6.1%. Both indices are well below the long term mean of the time series.

The observed fluctuations in *P. montagui* female SSB resulted in the placement of the resource in the cautious zone in 2015/16. In 2016/17, due to an increase in the SSB, the resource moved to well above the Upper Stock reference. Similar situations have occurred repeatedly during the assessment time series (Figure 35). Therefore, given the uncertainty in the female SSB index, observed dramatic changes need to be interpreted with caution.

Reference Points

Siferd (2015) suggested that reference points in the EAZ should be considered with caution due to the rather suboptimal (short) time series they were based on. Given the lack of historical background and the fact that reference points were initially developed for SFA2EX alone and subsequently applied to the entire EAZ, there is a need to develop new reference points. The reference points would have to be based on a larger dataset and include data points from the entire EAZ.

WESTERN ASSESSMENT ZONE

Survey Area Results

The first DFO-NSRF conducted survey of the WAZ was completed in 2014. In 2016, the third consecutive survey was done between August 4 and 11. Sixty seven of the 69 stations allocated were successfully completed.

Bottom Temperature

The only factor that could potentially influence the results of the area-weighted mean bottom temperature analysis is the timing of the surveys and not the instruments used to record the measurements or the ship used. Because of that, we feel confident that the time series for bottom temperature can be used in its entirety i.e. from 2007 onwards. Bottom temperature in the WAZ averaged about 0.5 °C in 2007 and 2009, increased to 1.5 °C in 2011 and then returned to the declining trend since (Figure 4c). We believe that the timing of the surveys is not a factor as the first two surveys were at similar times but the last three were several weeks earlier. In 2016, the area was the coldest of the time series with a mean of -0.4 °C. A much greater proportion of the WAZ was occupied by water below -1 °C in 2016 than a year before.

Western Assessment Zone – *P. borealis*

Similar to previous years, the main catches of *P. borealis* in 2015 and 2016 were found in Hudson Strait, in the northern portion of the WAZ (Figures 36 and 37). This distribution appears to corresponds well with the presence of a warm water (> 0 °C) intrusion from the North Atlantic extending into Hudson Strait (Figures 38 and 39). Although *P. borealis* can sometimes be found in water below 0 °C, 9 of the 24 stations sampled in 2015 and 33 of the 51 stations sampled in 2016 were below 0 °C and had no *P. borealis*. The remaining samples had only small catches.

Total, fishable and female spawning stock biomass indices are shown in Table 5 and Figure 40. Since the new time series began in 2014, results of prior surveys conducted by DFO are included, but cannot be considered directly comparable. The 2016 survey was the third consecutive survey in the series. Because of the relatively low number of survey data points and considerable uncertainty surrounding biomass indices, no trend can be inferred at this time. In 2016, the total biomass was 13,725 t (down from 30,930 t in 2015), fishable biomass was 13,116 t (down from 28,532 t in 2015) and female spawning stock biomass was 8,015 t (down from 14,710 t in 2015).

Historical background in regards to how management system changed over time can be found in Siferd (2015).

Only 17% and 31% of the TAC were taken in 2015/16 and 2016/17, respectively (Figure 41). Even though the TAC was not taken, this does not reflect the status of the stock in the area. Low percentages of catches for *P. borealis* stem from the fact that it is hard, according to the fishers' reports, to obtain a clean catch of this species in the WAZ. Since the fishery in the WAZ is focused on *P. montagui*, once the TAC of this species is fully taken, fishing ceases in the WAZ. This results in low catches of *P. borealis* and as a consequence, the reported *P. borealis* exploitation rate index was low in 2016/17, at 4.9% (Figure 42a). The potential exploitation rate index was 15.9% (Figure 42b). This higher potential exploitation rate resulted from the decline in the overall biomass in 2016 in comparison to 2015. In 2016, fishers reported a higher proportion of *P. borealis* in *P. montagui* directed fishing efforts.

Western Assessment Zone – *P. montagui*

The largest catches of *P. montagui* are found in Hudson Strait and the northeast corner of Ungava Bay (Figures 43 and 44). The populations of *P. montagui* and *P. borealis* overlap to a great extent in the WAZ; however, it appears that *P. montagui* has an affinity for cooler waters (Figures 45 and 46).

Total, fishable and female spawning stock biomasses are shown in Table 6 and Figure 47. Although previous surveys conducted by DFO are included, they are not considered directly comparable to the start of the new time series. The 2016 survey was the third consecutive survey in the new time series. Declines were observed in the biomass indices over the last three years, however, considering the relatively short time series and relatively large confidence intervals, the trend cannot be assessed with high certainty. Total biomass in 2016 was 35,385 t (down from 71,209 t in 2015), fishable biomass was 31,724 t (down from 49,582 t in 2015) and female spawning stock biomass was 18,691 t (down from 27,324 t in 2015).

From 1979 through 1991 only six years had catches recorded in what is currently known as the WAZ (Figure 48). Over the next two decades no catch was recorded until the 2010/11 fishing year, after DFO surveys in 2007 and 2009 renewed interest in the area (DFO 2008, 2010). Catches increased in the following two seasons, however, the significant increase occurred when a new management system was implemented in 2013/14 (see Siferd 2015). In 2013/14, 4,867 t of the new 5,000 t TAC was taken. The TAC was increased to 5,860 t for the 2014/15 fishing year, and increased again to 6,138 t in 2015/16. The same TAC was maintained in 2016/17, and virtually all of it (99%) was taken (Table 4). Fishers reported that the shrimp were found in a relatively more concentrated area in 2016, enabling more efficient fishing in comparison to previous years. With the entire TAC taken the exploitation rate index would be 19.3% (Figure 49). Historically, the harvest rate was set purposely low in comparison to other SFAs (Siferd 2015) in order to develop the fishery slowly, an objective expressed by all stakeholders and DFO when the new management system was developed. Last year's, 2016, decline in biomass caused the exploitation index reach a level not previously observed in this stock.

Reference Points

Reference points for the WAZ had been created based on results from the biennial DFO surveys in 2007–2011 (Siferd 2014). These reference points were deemed not valid due to the change in survey vessel, gear and timing, which started a new survey time series (beginning of the DFO-NSRF survey in WAZ). Because no standardization between the previous and surveys has taken place, results from the two surveys cannot be compared directly, making the PA framework that was developed using data from the old survey no longer valid under the new time series. At least five successfully completed surveys are required before new reference points could be developed for the WAZ.

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TABLES AND FIGURES

Table 1. Total, fishable and female spawning stock biomass indices (t) for Pandalus borealis *in the Eastern Assessment Zone for the 2006–2016 surveys. Lower confidence limit (LCL) and upper confidence limit (UCL) represent the 95% confidence range.*

Year	Biomass	Weight (t)		
		Mean	LCL	UCL
2016	Total	68,079.42	44,318	96,479
2015	Total	80,458.29	52,380	108,696
2014	Total	51,409.71	39,659	63,161
2013	Total	50,421.46	38,679	61,927
2012	Total	60,985.45	43,497	80,408
2011	Total	83,461.84	23,956	143,793
2010	Total	71,887.38	41,392	108,846
2009	Total	81,363.27	51,479	113,556
2008	Total	51,581.26	37,757	67,137
2007	Total	43,827.19	31,480	58,333
2006	Total	33,633.55	22,700	45,511
2016	Fishable	65,569.87	42,137	93,569
2015	Fishable	78,984.09	50,852	106,962
2014	Fishable	50,457.99	38,914	62,340
2013	Fishable	49,696.90	38,427	60,631
2012	Fishable	60,533.67	43,074	79,960
2011	Fishable	78,530.23	23,900	135,037
2010	Fishable	71,064.51	40,234	108,703
2009	Fishable	78,754.88	48,850	110,115
2008	Fishable	51,053.43	37,117	66,708
2007	Fishable	43,305.97	31,015	58,346
2006	Fishable	32,815.89	21,969	44,152
2016	Female SS	34,827.08	24,220	46,979
2015	Female SS	60,869.47	33,379	88,386
2014	Female SS	34,069.42	25,157	43,000
2013	Female SS	32,049.10	26,762	37,607
2012	Female SS	41,189.85	29,498	54,383
2011	Female SS	47,806.80	13,470	82,926
2010	Female SS	43,800.31	19,025	79,665
2009	Female SS	38,856.32	23,122	56,820
2008	Female SS	27,653.12	22,507	39,368
2007	Female SS	27,698.44	19,249	39,007
2006	Female SS	16,805.06	10,523	23,026

Table 2. Quota (t), adjusted quota (t; after bridging) and catch (t) reported by CAQR for Pandalus borealis *in SFA 2 and 3 1988–2012/13 after which the area was converted to SFA Davis Strait (DS), Nunavut (NU), and Nunavik (NK).*

Management Year[1]	Shrimp Fishing Area or Quota Area									Shrimp Fishing Area or Management Unit								
	SFA2EX			SFA2CM			SFA3[2]			Davis Strait East			DS- W + NU-E + NK-E			NU-W + NK-W		
	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
1988	-	-	-	-	-	2,826	-	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	3,500	-	3,039	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	3,500	-	1,771	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	3,485	-	1,098	-	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	3,485	-	1,239	-	-	-	-	-	-	-	-	-	-	-	-
1993	-	-	-	3,485	-	106	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	3,500	-	475	-	-	-	-	-	-	-	-	-	-	-	-
1995	-	-	-	3,500	-	2,721	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	3,500	-	3,968	-	-	-	-	-	-	-	-	-	-	-	-
1997	-	-	-	5,250	-	5,235	-	-	-	-	-	-	-	-	-	-	-	-
1998	-	-	-	5,250	-	5,163	-	-	41	-	-	-	-	-	-	-	-	-
1999	3,500	3,500	105	5,250	5,250	5,027	-	-	0	-	-	-	-	-	-	-	-	-
2000	3,500	3,500	237	5,353	5,353	4,024	-	-	0	-	-	-	-	-	-	-	-	-
2001	3,500	3,500	394	5,250	5,250	5,435	-	-	0	-	-	-	-	-	-	-	-	-
2002	3,500	3,500	64	5,250	5,250	5,533	-	-	0	-	-	-	-	-	-	-	-	-
2003/04	3,500	3,500	31	5,250	5,250	4,792	-	-	0	-	-	-	-	-	-	-	-	-
2004/05	3,500	3,500	212	5,250	5,250	5,019	-	-	0	-	-	-	-	-	-	-	-	-
2005/06	3,520	3,520	736	5,253	5,253	5,466	-	-	0	-	-	-	-	-	-	-	-	-
2006/07	3,480	3,480	725	5,247	5,247	5,241	400	400	90	-	-	-	-	-	-	-	-	-
2007/08	3,500	3,500	529	5,250	5,250	5,781	400	400	406	-	-	-	-	-	-	-	-	-
2008/09	3,500	3,500	213	5,250	5,192	4,898	400	400	0	-	-	-	-	-	-	-	-	-
2009/10	3,500	3,465	1,030	5,250	4,660	4,399	400	400	0	-	-	-	-	-	-	-	-	-

Management Year[1]	Shrimp Fishing Area or Quota Area									Shrimp Fishing Area or Management Unit								
	SFA2EX			SFA2CM			SFA3[2]			Davis Strait East			DS- W + NU-E + NK-E			NU-W + NK-W		
	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
2010/11	3,500	3,483	802	5,250	5,797	5,721	400	400	53	-	-	-	-	-	-	-	-	-
2011/12	3,500	3,201	2,557	5,250	5,302	5,298	400	400	161	-	-	-	-	-	-	-	-	-
2012/13	3,500	3,763	654	5,250	5,329	4,666	400	400	246	-	-	-	-	-	-	-	-	-
2013/14	-	-	-	-	-	-	-	-	-	3,500	3,157	978	5,500	6,166	6,132	1,500	1,500	933
2014/15	-	-	-	-	-	-	-	-	-	3,208	3,208	105	5,042	5,042	4,867	2,080	2,080	847
2015/16	-	-	-	-	-	-	-	-	-	3,208	3,208	158	5,042	5,042	4,658	2,080	2,080	353
2016/17[3]	-	-	-	-	-	-	-	-	-	3,208	3,208	854	6,280	6,280	4,759	2,080	2,080	1,059

[1] Management Year changed from calendar to fiscal in 2003. 2003/04 season 15 months during the conversion period.

[2] *P. borealis* by-catch to be fished within SFA3 and SFA2 within the NSA while directing for *P. montagui*.

[3] CAQR as of February 2, 2017 may be preliminary as fishery on-going.

Table 3. Total, fishable and female spawning stock biomass indices (t) for Pandalus montagui *in the Eastern Assessment Zone for the 2006–2016 surveys. Lower confidence limit (LCL) and upper confidence limit (UCL) represent the 95% confidence range.*

Year	Biomass	Weight (t)		
		Mean	LCL	UCL
2016	Total	15,411.92	8,206	22,756
2015	Total	6,708.77	3,858	9,346
2014	Total	17,589.36	11,922	23,295
2013	Total	3,651.01	1,822	6,367
2012	Total	29,966.61	8,922	50,956
2011	Total	8,729.02	3,266	16,395
2010	Total	7,860.38	6,089	9,795
2009	Total	17,437.62	7,427	32,323
2008	Total	16,088.04	8,421	23,642
2007	Total	7,587.20	4,378	11,042
2006	Total	2,833.27	255	5,412
2016	Fishable	13,791.57	6,452	21,126
2015	Fishable	6,136.90	3,445	8,629
2014	Fishable	16,599.97	11,203	22,084
2013	Fishable	3,524.28	1,738	6,208
2012	Fishable	28,845.47	8,582	48,946
2011	Fishable	7,739.99	2,871	14,285
2010	Fishable	7,422.75	5,714	9,290
2009	Fishable	15,679.12	6,190	29,774
2008	Fishable	14,667.04	7,287	21,973
2007	Fishable	4,828.25	3,389	6,673
2006	Fishable	2,667.14	210	5,122
2016	Female SS	10,056.16	2,986	17,280
2015	Female SS	3,876.62	2,085	5,452
2014	Female SS	12,696.30	8,834	16,622
2013	Female SS	2,777.54	1,301	4,949
2012	Female SS	23,552.02	6,218	40,985
2011	Female SS	3,124.24	1,599	4,721
2010	Female SS	5,819.1	4,509	7,136
2009	Female SS	8,775.54	4,205	13,955
2008	Female SS	10,659.82	4,269	17,047
2007	Female SS	1,970.63	903	3,490
2006	Female SS	2,134.38	50	4,219

Table 4. Quota (t), adjusted quota (t; after bridging) and catch (t) reported by CAQR for Pandalus montagui *in SFA 2 and 3 1988–2012/13 after which the area was converted to SFA Davis Strait (DS), Nunavut (NU) and Nunavik (NK).*

Management Year[1]	Shrimp Fishing Area or Quota Area									Shrimp Fishing Area or Management Unit								
	SFA2[2]			SFA3[2]			2,3,4 Quota[3]			Davis Strait			NU-E + NK-E			NU-W + NK-W		
	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
1978	-	-	-	-	-	-	100	-	0	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	100	-	92	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	200	-	236	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	200	-	13	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	200	-	0	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	850	-	0	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	850	-	0	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	850	-	0	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	850	-	476	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	1,200	-	1,069	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	1,200	-	1,125	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	1,200	-	1,269	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	2,280	-	1,635	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	1,190	-	605	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	1,190	-	0	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	1,190	-	0	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	1,200	-	244	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	1,200	-	245	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	1,200	-	0	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	1,200	-	435	-	-	-	-	-	-	-	-	-
1998	-	-	-	500	-	0	3,300	3,300	2,205	-	-	-	-	-	-	-	-	-
1999	-	-	-	500	-	0	3,300	3,300	3,714	-	-	-	-	-	-	-	-	-

Management Year[1]	Shrimp Fishing Area or Quota Area									Shrimp Fishing Area or Management Unit								
	SFA2[2]			SFA3[2]			2,3,4 Quota[3]			Davis Strait			NU-E + NK-E			NU-W + NK-W		
	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
2000	-	-	-	500	-	0	3,300	3,300	3,005	-	-	-	-	-	-	-	-	-
2001	-	-	-	500	-	0	3,300	3,300	3,751	-	-	-	-	-	-	-	-	-
2002	2,000	2,000	0	1,000	1,000	0	4,300	4,300	3,369	-	-	-	-	-	-	-	-	-
2003/04	2,000	2,000	0	1,000	1,000	0	3,800	3,800	1,053	-	-	-	-	-	-	-	-	-
2004/05	2,000	2,000	0	1,000	1,000	0	3,300	3,300	2,069	-	-	-	-	-	-	-	-	-
2005/06	2,000	2,000	465	1,000	1,000	176	3,300	3,300	1,658	-	-	-	-	-	-	-	-	-
2006/07	2,000	2,000	0	1,000	1,000	264	3,300	3,300	2,167	-	-	-	-	-	-	-	-	-
2007/08	2,000	2,000	197	1,000	1,000	341	3,300	3,300	606	-	-	-	-	-	-	-	-	-
2008/09	2,000	2,000	0	1,000	1,000	0	3,300	3,300	645	-	-	-	-	-	-	-	-	-
2009/10	2,000	2,000	0	1,000	1,000	0	3,300	3,300	480	-	-	-	-	-	-	-	-	-
2010/11	2,000	2,000	23	1,000	1,000	310	3,300	3,094	554	-	-	-	-	-	-	-	-	-
2011/12	2,000	2,000	23	1,000	1,000	836	3,300	2,778	706	-	-	-	-	-	-	-	-	-
2012/13	2,000	2,000	92	1,000	1,000	981	3,300	3,527	1,081	-	-	-	-	-	-	-	-	-
2013/14	-	-	-	-	-	-	-	-	-	1,100	971	79	1,150	1,150	871	5,000	5,000	4,775
2014/15	-	-	-	-	-	-	-	-	-	410	410	98	430	430	303	5,860	5,860	5,836
2015/16	-	-	-	-	-	-	-	-	-	410	410	48	430	430	12	6,138	6,138	4,616
2016/17	-	-	-	-	-	-	-	-	-	410	410	97	430	430	244	6,138	6,138	6,071

[1] Management Year changed from calendar to fiscal in 2003. 2003/04 season 15 months during the conversion period.
[2] Nunavut special allocation. Quota to be fished in SFA 2 and 3 within the NSA only.
[3] *P. montagui* to be fished by license holders within SFA 2, 3 and 4 west of 63 °W.
[4] CAQR as of February 2, 2017 may be preliminary as fishery on-going.

Table 5. Total, fishable and female spawning stock biomass indices (t) for Pandalus borealis *in the Western Assessment Zone for the 2007, 2009, 2011 and 2013 surveys conducted by DFO and the 2014–16 survey by the DFO-NSRF . Lower confidence limit (LCL) and upper confidence limit (UCL) represent the 95% confidence range.*

Year	Biomass	Weight (t)		
		Mean	LCL	UCL
2016	Total	13,725.21	8,079	19,955
2015	Total	30,929.99	20,258	42,366
2014	Total	22,673.91	14,640	32,979
2013	Total	22,134.74	16,029	28,386
2011	Total	21,491.90	13,714	30,399
2009	Total	18,401.51	8,760	30,301
2007	Total	16,120.80	5,497	31,243
2016	Fishable	13,116.23	7,867	18,868
2015	Fishable	28,532.16	18,531	39,501
2014	Fishable	21,712.50	14,353	31,046
2013	Fishable	21,998.56	15,906	28,518
2011	Fishable	19,692.10	12,468	27,961
2009	Fishable	15,543.95	7,613	25,529
2007	Fishable	14,614.98	4,907	28,872
2016	Female SS	8,014.94	4,780	11,590
2015	Female SS	14,710.39	9,270	20,379
2014	Female SS	12,308.93	8,792	16,398
2013	Female SS	9,785.03	7,106	12,829
2011	Female SS	6,376.60	4,182	8,909
2009	Female SS	3,839.38	1,154	7,479
2007	Female SS	3,231.03	1,687	5,361

Table 6. Total, fishable and female spawning stock biomass indices (t) for Pandalus montagui *in the Western Assessment Zone for the 2007, 2009, 2011 and 2013 surveys conducted by DFO and the 2014–16 survey by the DFO-NSRF. Lower confidence limit (LCL) and upper confidence limit (UCL) represent the 95% confidence range.*

Year	Biomass	Weight (t)		
		Mean	LCL	UCL
2016	Total	35,385.14	22,276	49,582
2015	Total	71,209.03	40,881	108,035
2014	Total	86,239.33	50,609	12,516
2013	Total	50,272.52	36,664	65,238
2011	Total	77,142.30	45,030	121,559
2009	Total	65,044.31	31,655	112,124
2007	Total	78,064.38	19,755	155,041
2016	Fishable	31,724.17	19,507	44,908
2015	Fishable	55,194.40	35,769	76,429
2014	Fishable	77,077.74	44,854	111,562
2013	Fishable	45,647.22	32,899	59,438
2011	Fishable	71,557.90	40,264	108,612
2009	Fishable	46,672.87	25,756	73,342
2007	Fishable	54,044.48	17,007	99,461
2016	Female SS	18,690.62	11,090	27,334
2015	Female SS	27,323.60	18,282	37,041
2014	Female SS	38,875.39	23,553	55,849
2013	Female SS	26,955.19	18,616	35,736
2011	Female SS	32,549.40	20,296	46,119
2009	Female SS	17,998.70	9,775	28,160
2007	Female SS	19,277.30	5,668	36,606

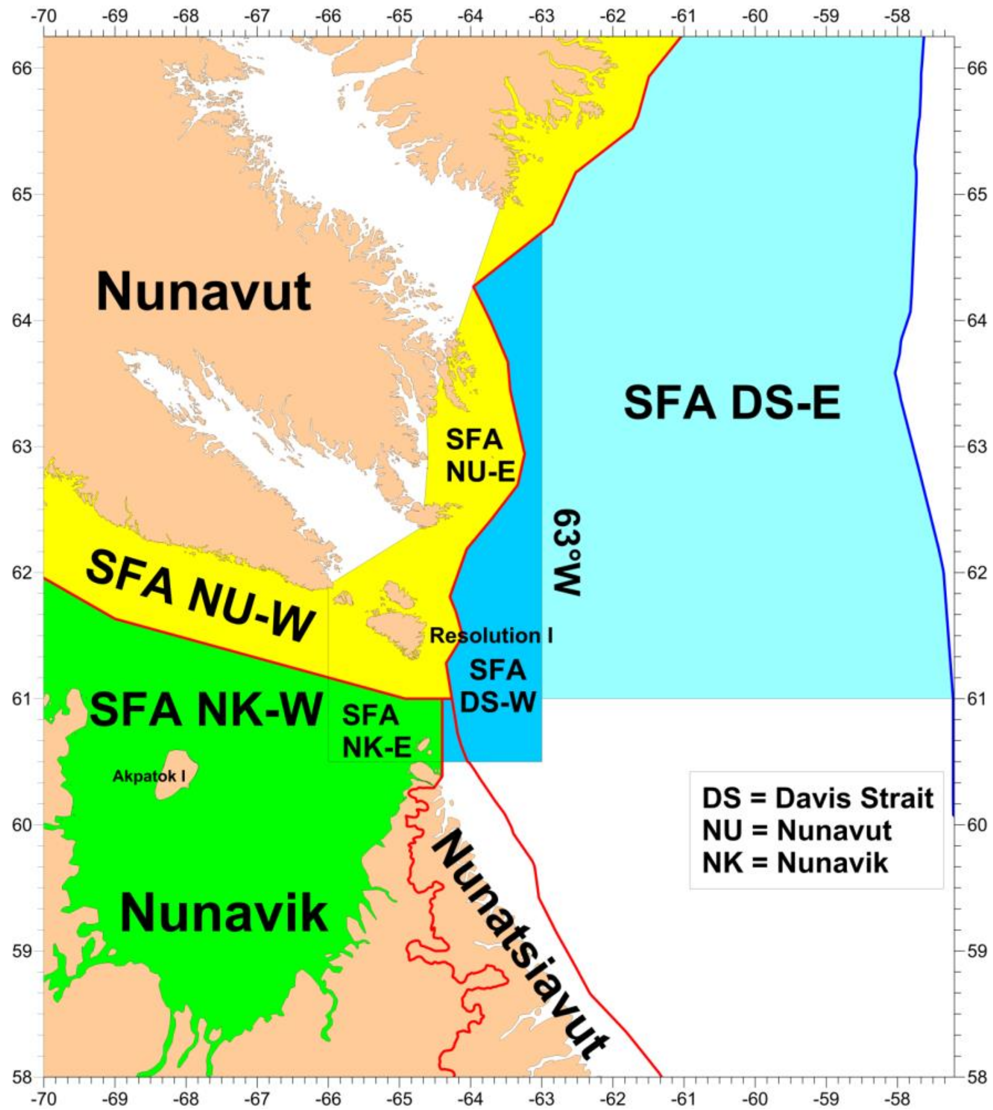

Figure 1. Shrimp Fishing Areas Nunavut (NU), Nunavik (NK) and Davis Strait (DS) and their East and West management units within DFO's Central and Arctic Region.

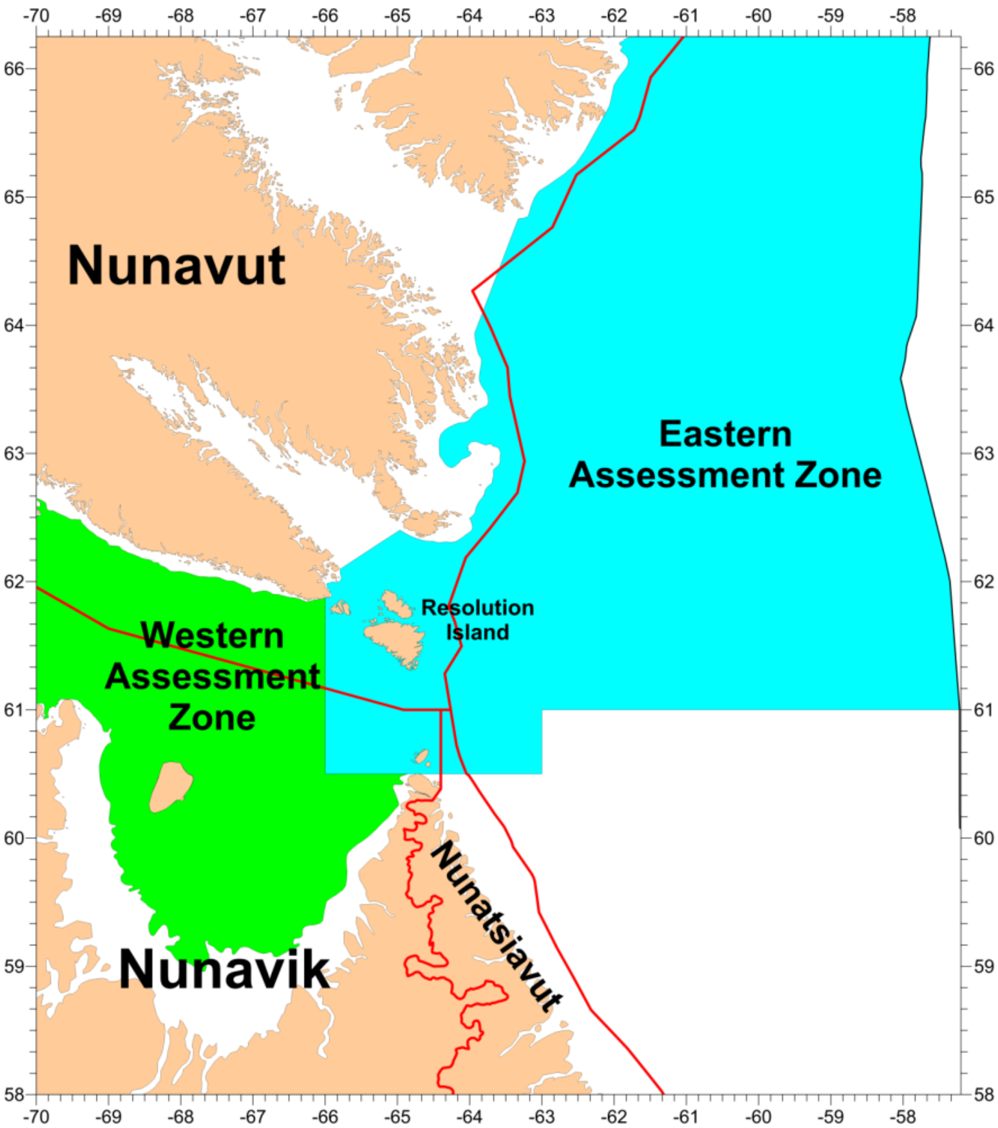

Figure 2. The Eastern (blue) and Western (green) Assessment Zones. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claims Areas.

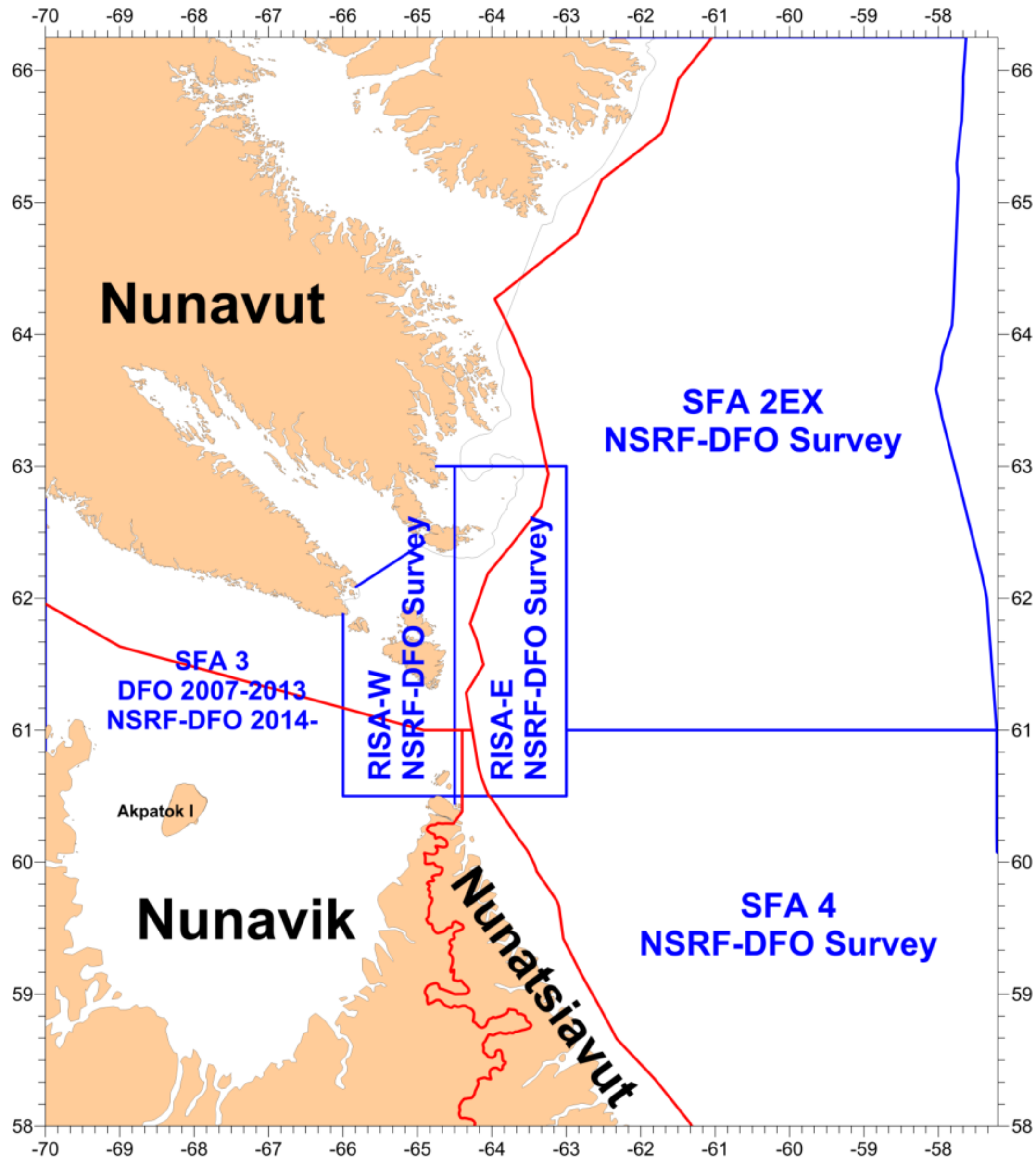

Figure 3. Location of the northern survey areas within the Eastern and Western Assessment Zones, Shrimp Fishing Area (SFA) 2 Exploratory (EX), Resolution Island Study Area (RISA)–East (E), RISA–West (W) and SFA 3, used in the assessment of domestic Canadian Pandalid Stocks by the DFO's Central and Arctic Region. SFA 4 is assessed by the DFO's Newfoundland and Labrador Region. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claim Areas.

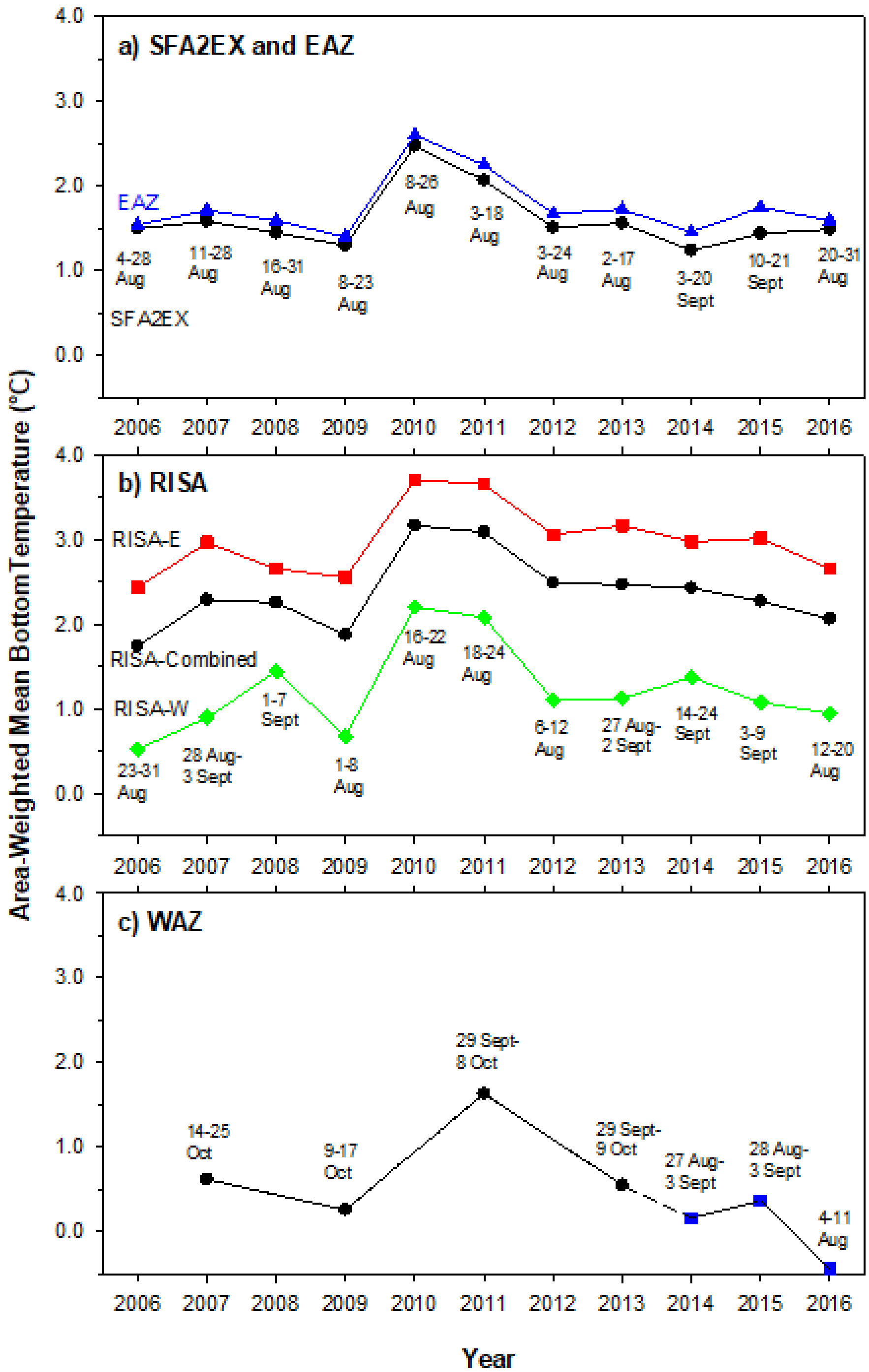

Figure 4. Mean area-weighted bottom temperatures in the Eastern Assessment Zone for a) SFA2EX (black circle) and EAZ (blue triangle), and b) RISA showing RISA combined (black circle), RISA-E (red square) and RISA-W (green diamond), and c) the Western Assessment Zone for the 2006–2016 surveys. Point label indicate the dates over which samples were taken.

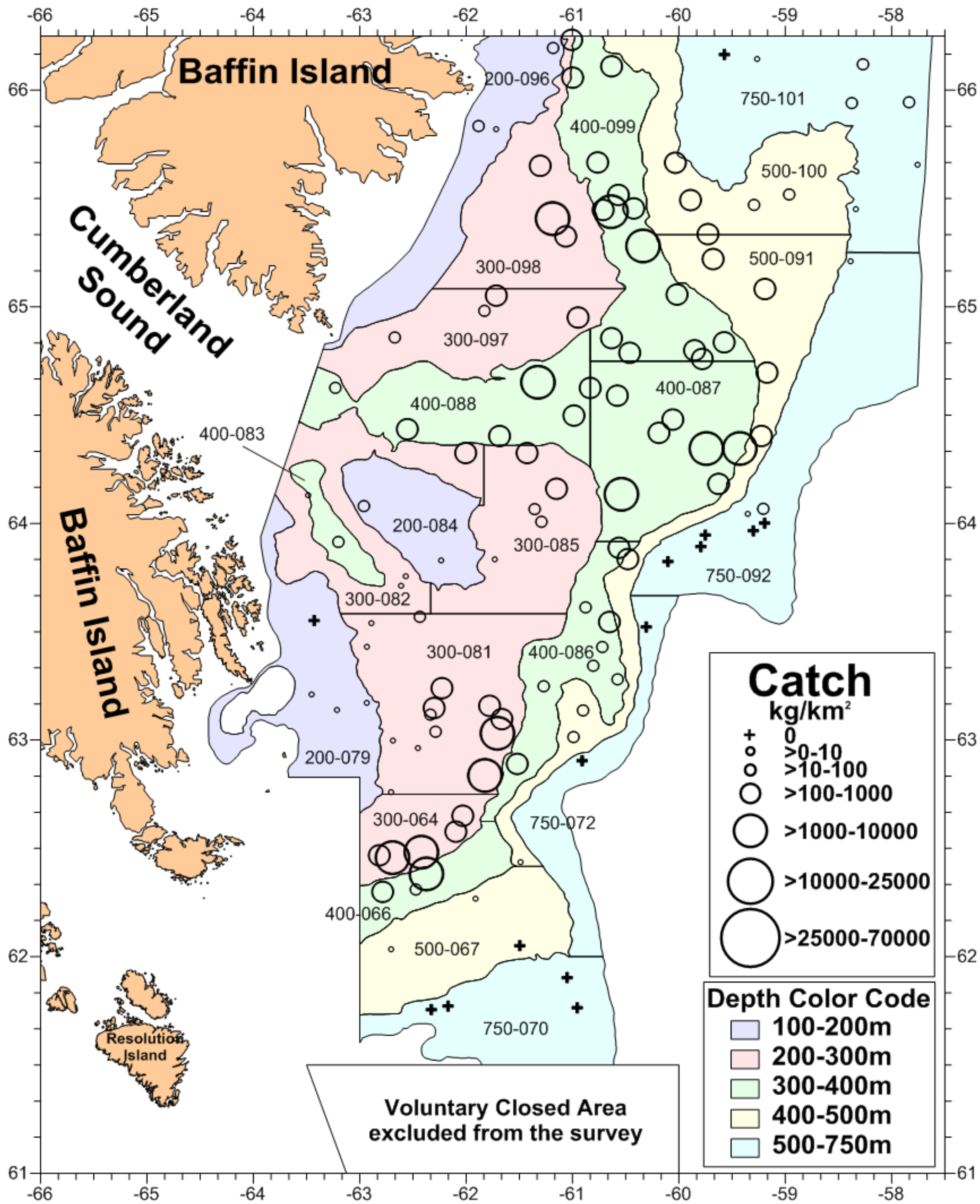

Figure 5. Standardized Pandalus borealis *catch (kg km^{-2}) from the 2015 SFA2EX survey area overlying the depth contours and strata of the survey area.*

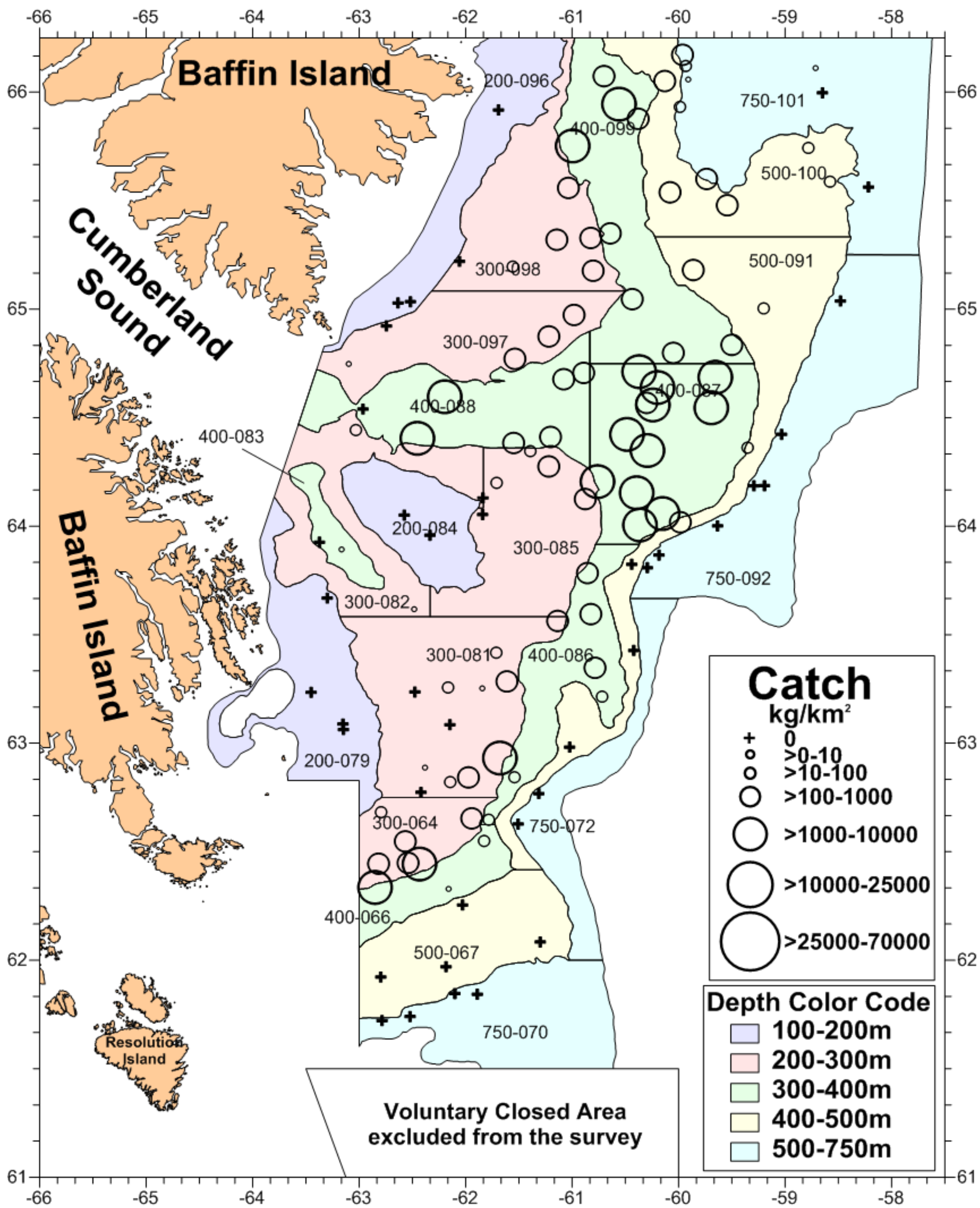

Figure 6. Standardized Pandalus borealis *catch (kg km^{-2}) from the 2016 SFA2EX survey area overlying the depth contours and strata of the survey area.*

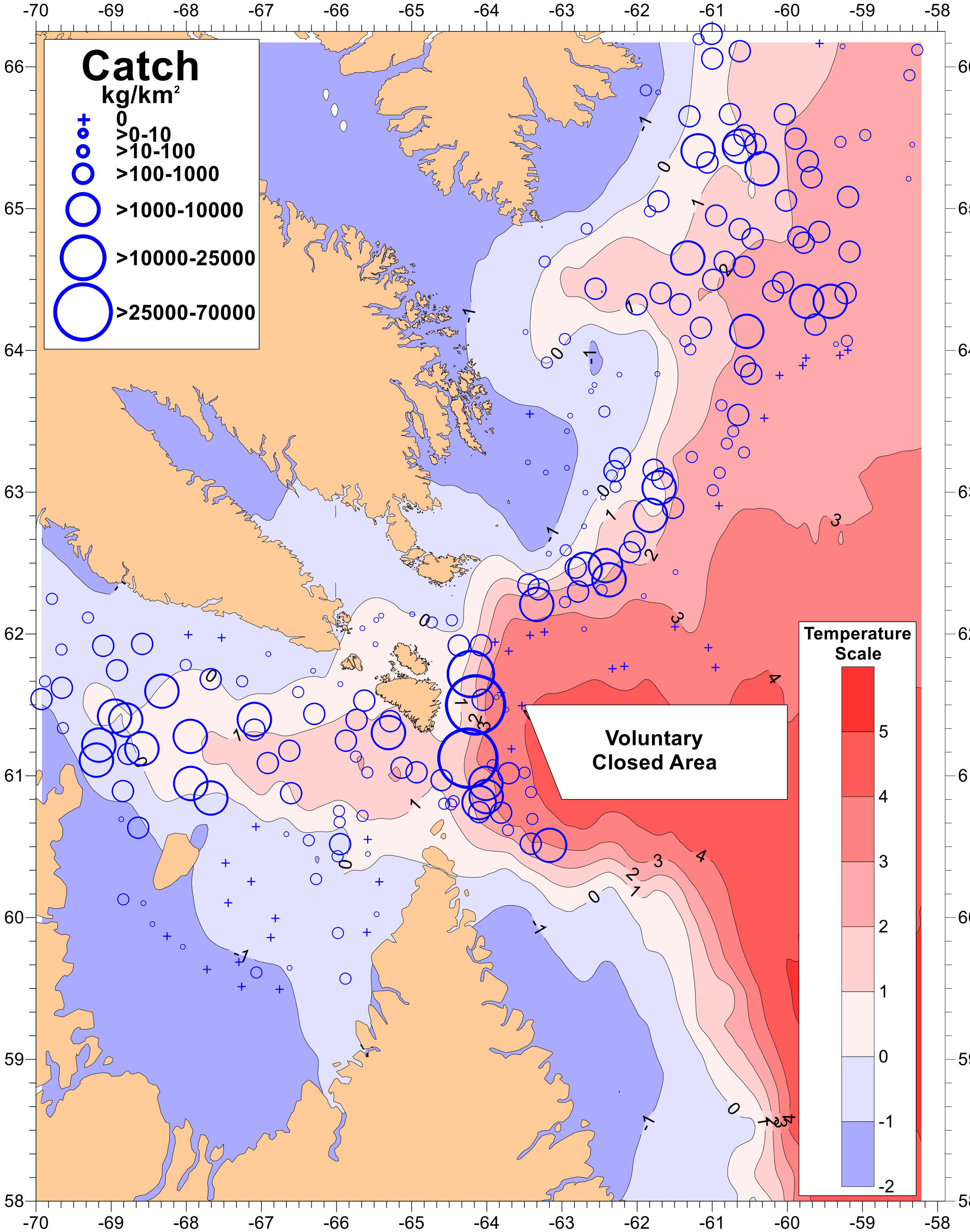

Figure 7. 2015 standardized Pandalus borealis *catch (blue symbols, kg km^{-2}) from the Eastern and Western Assessment Zones overlying the mean bottom temperature contours observed in the survey areas.*

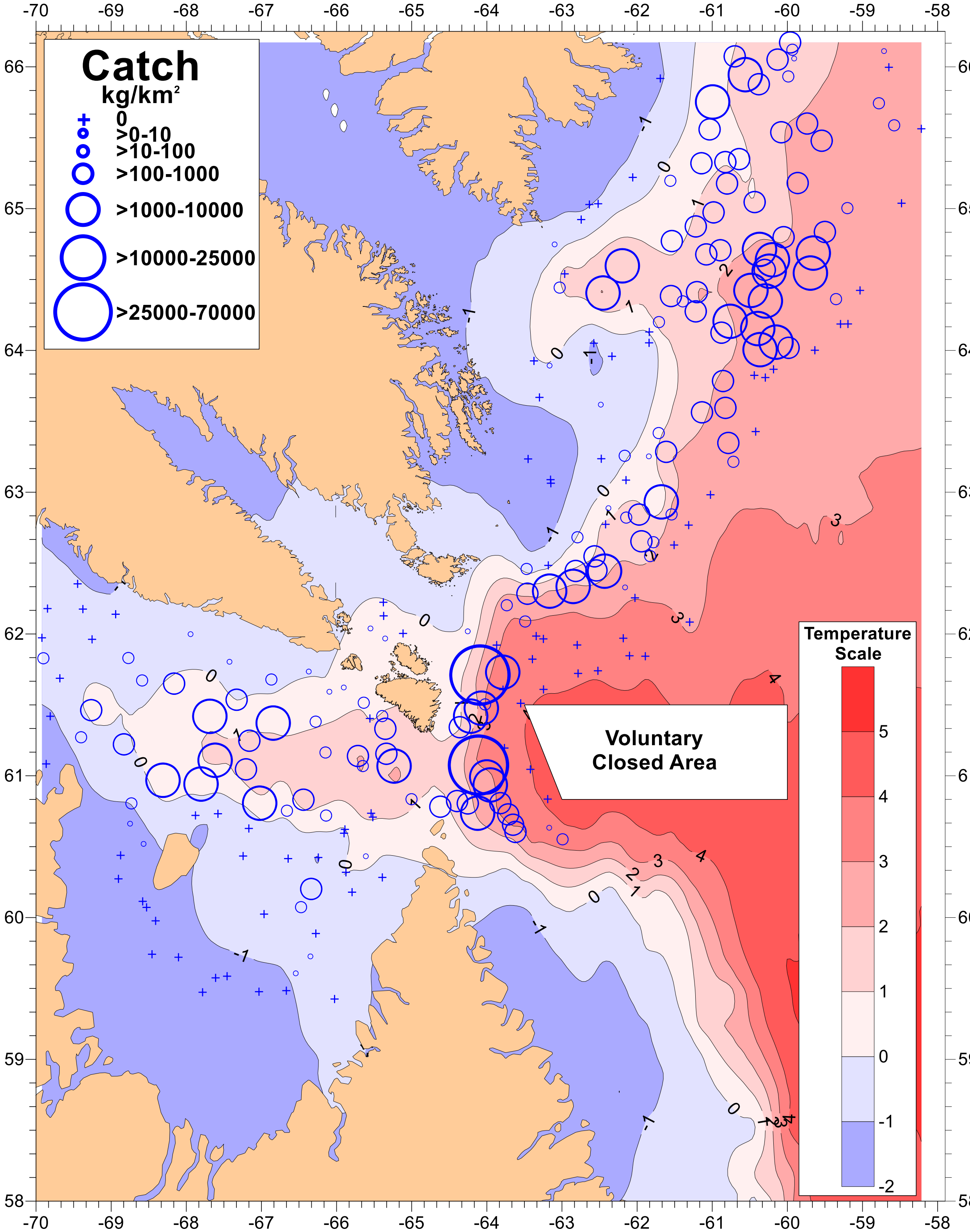

Figure 8. 2016 standardized Pandalus borealis *catch (blue symbols, kg km^{-2}) from the Eastern and Western Assessment Zones overlying mean bottom temperature contours observed in the survey areas.*

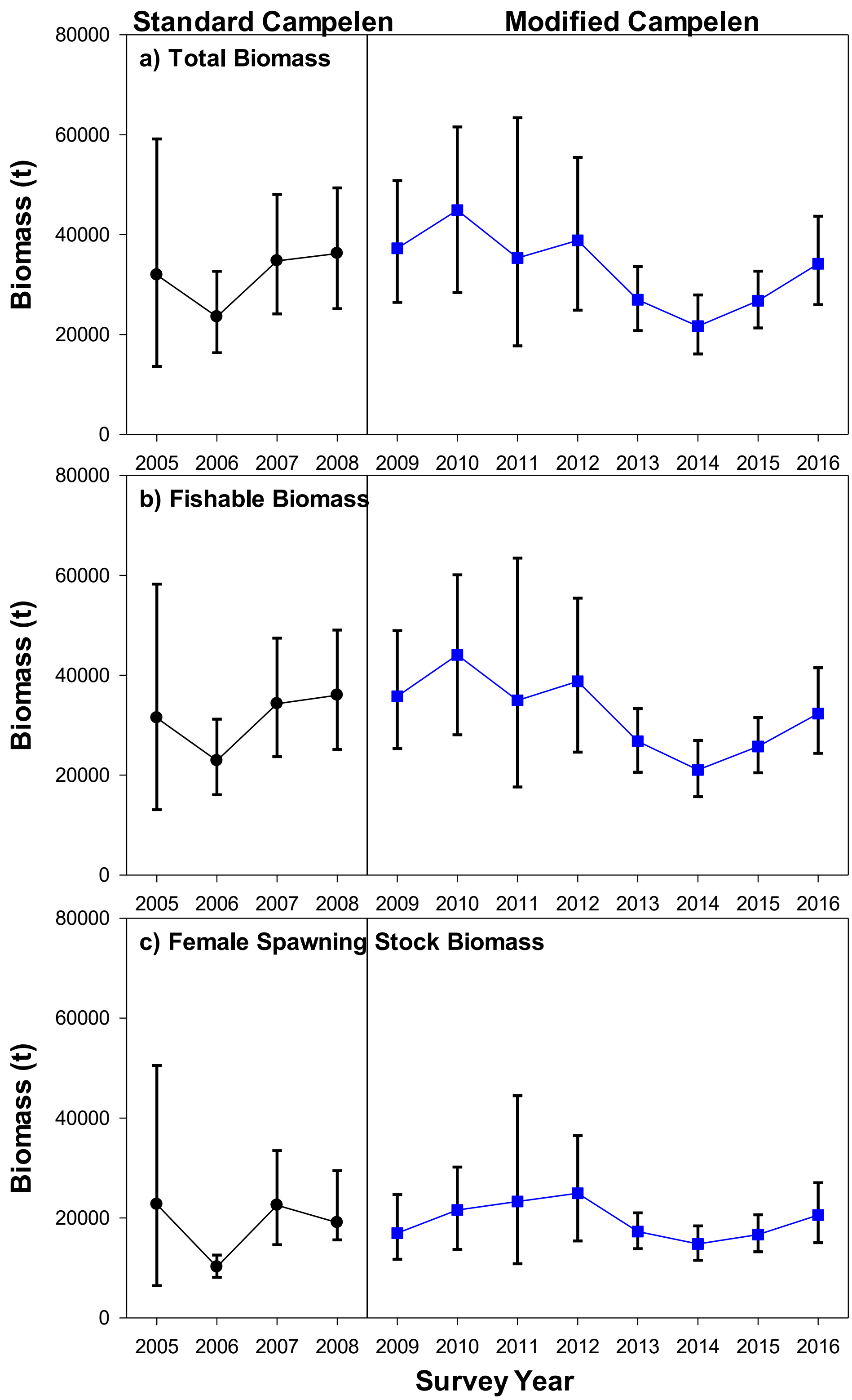

Figure 9. Total, fishable and female spawning stock biomass indices (t) of Pandalus borealis *in the SFA2EX survey area for the years 2005–2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

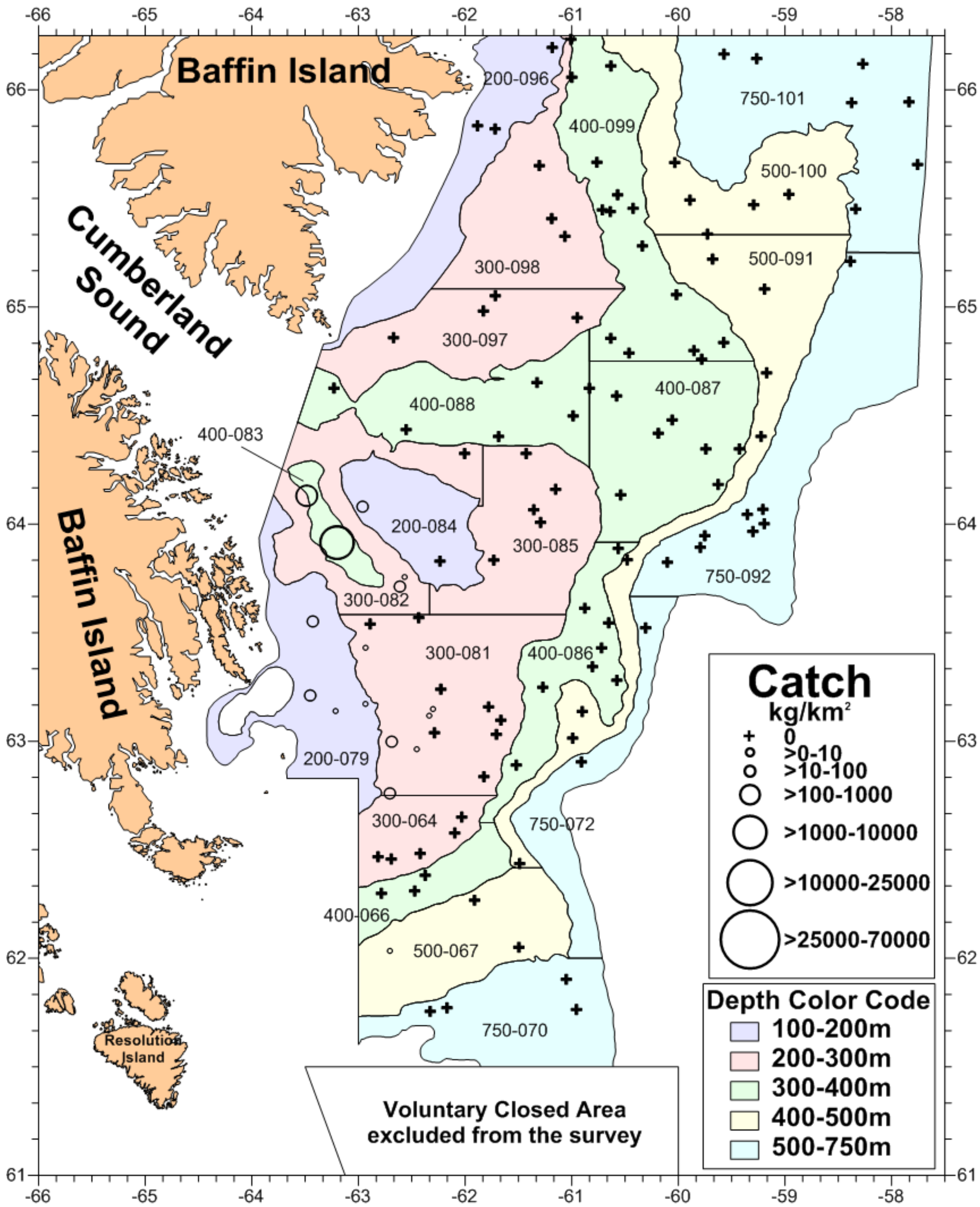

Figure 10. Standardized Pandalus montagui *catch (black symbols, kg km*$^{-2}$*) from the SFA2EX survey area in 2015 overlying the depth contours and strata of the survey area.*

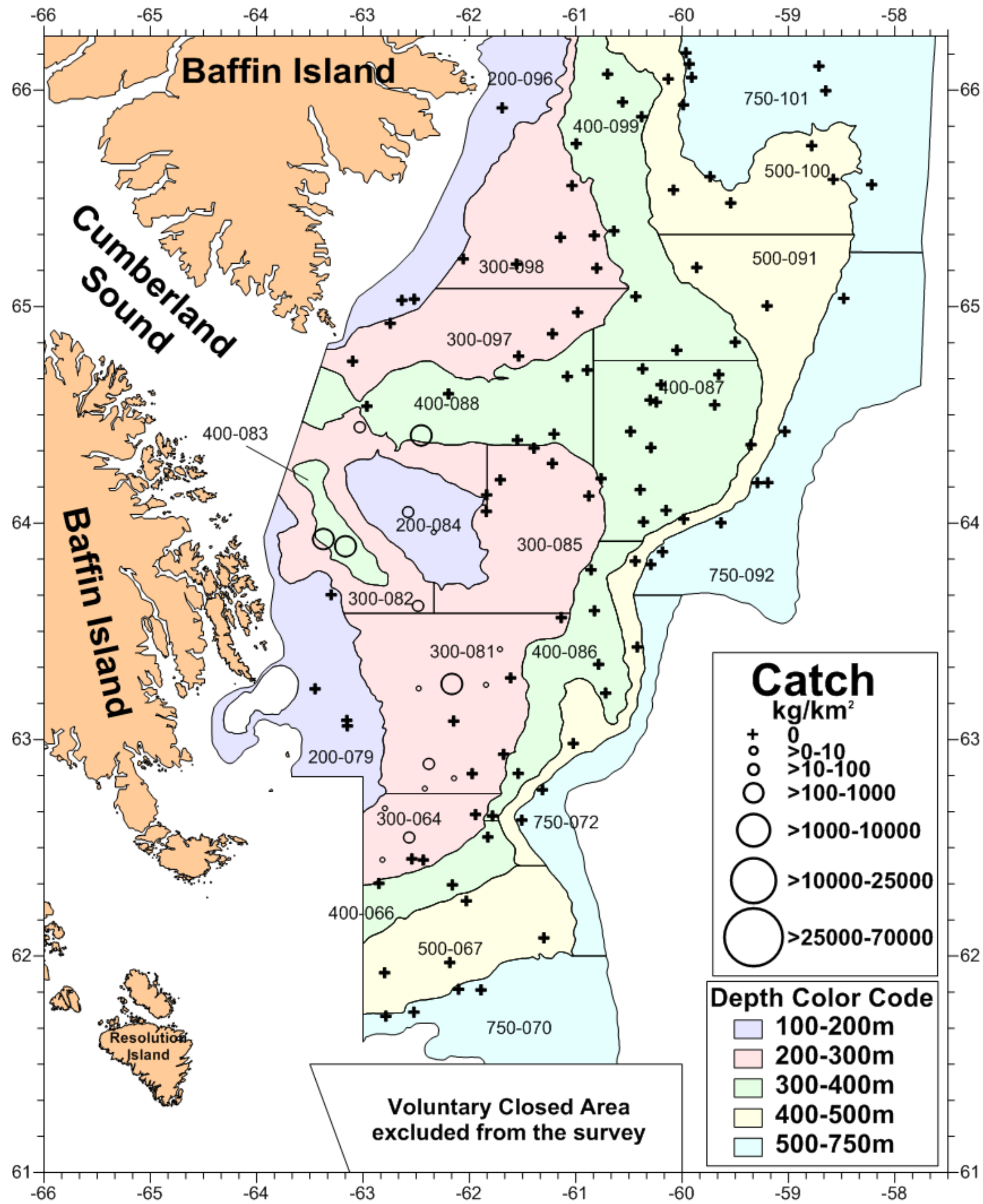

Figure 11. Standardized Pandalus montagui *catch (black symbols, kg km^{-2}) from the SFA2EX survey area in 2016 overlying the depth contours and strata of the survey area.*

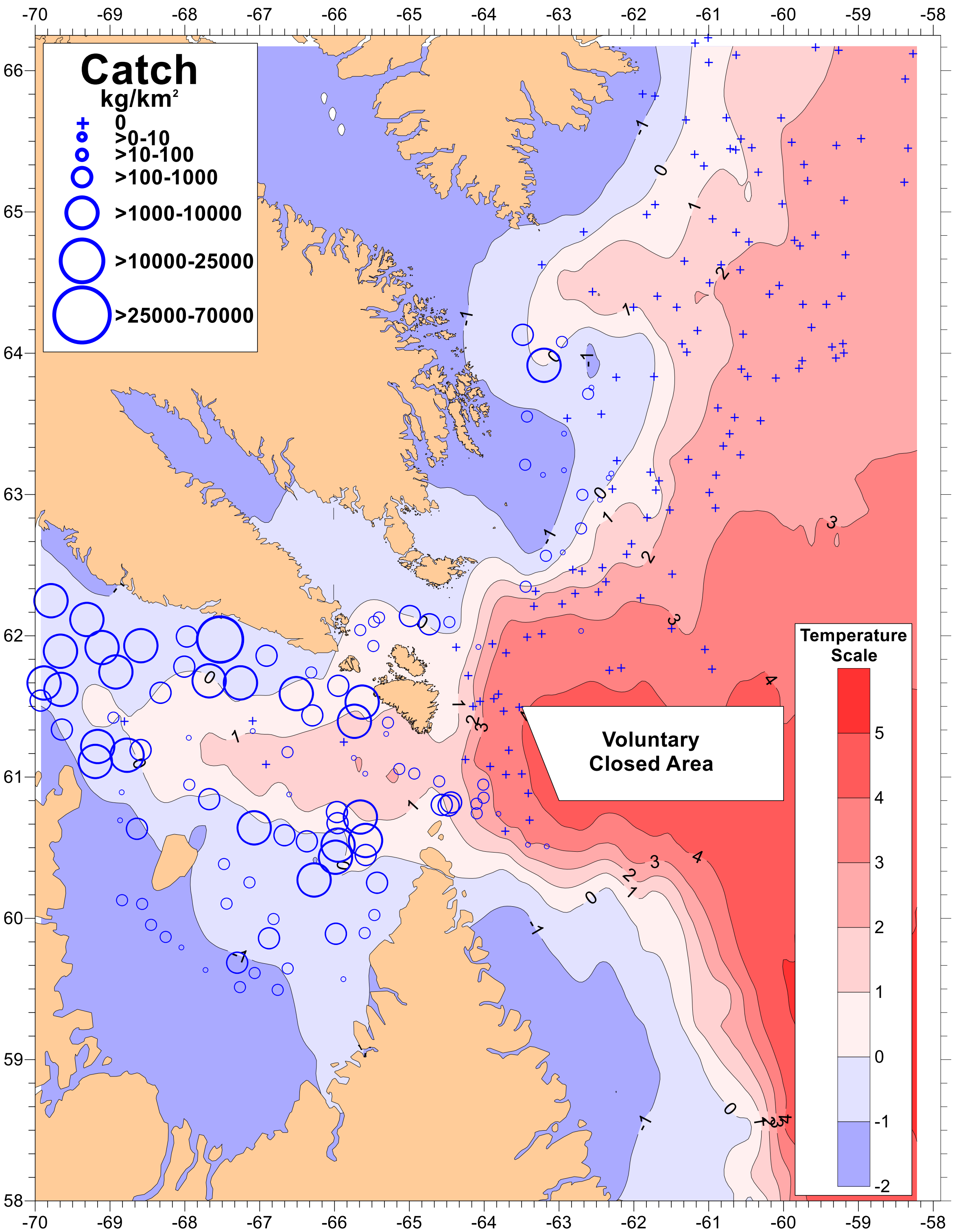

Figure 12. 2015 standardized Pandalus montagui *catch (blue symbols, kg km*$^{-2}$*) in the Eastern and Western Assessment Zones survey overlying the temperature contours observed in the survey areas.*

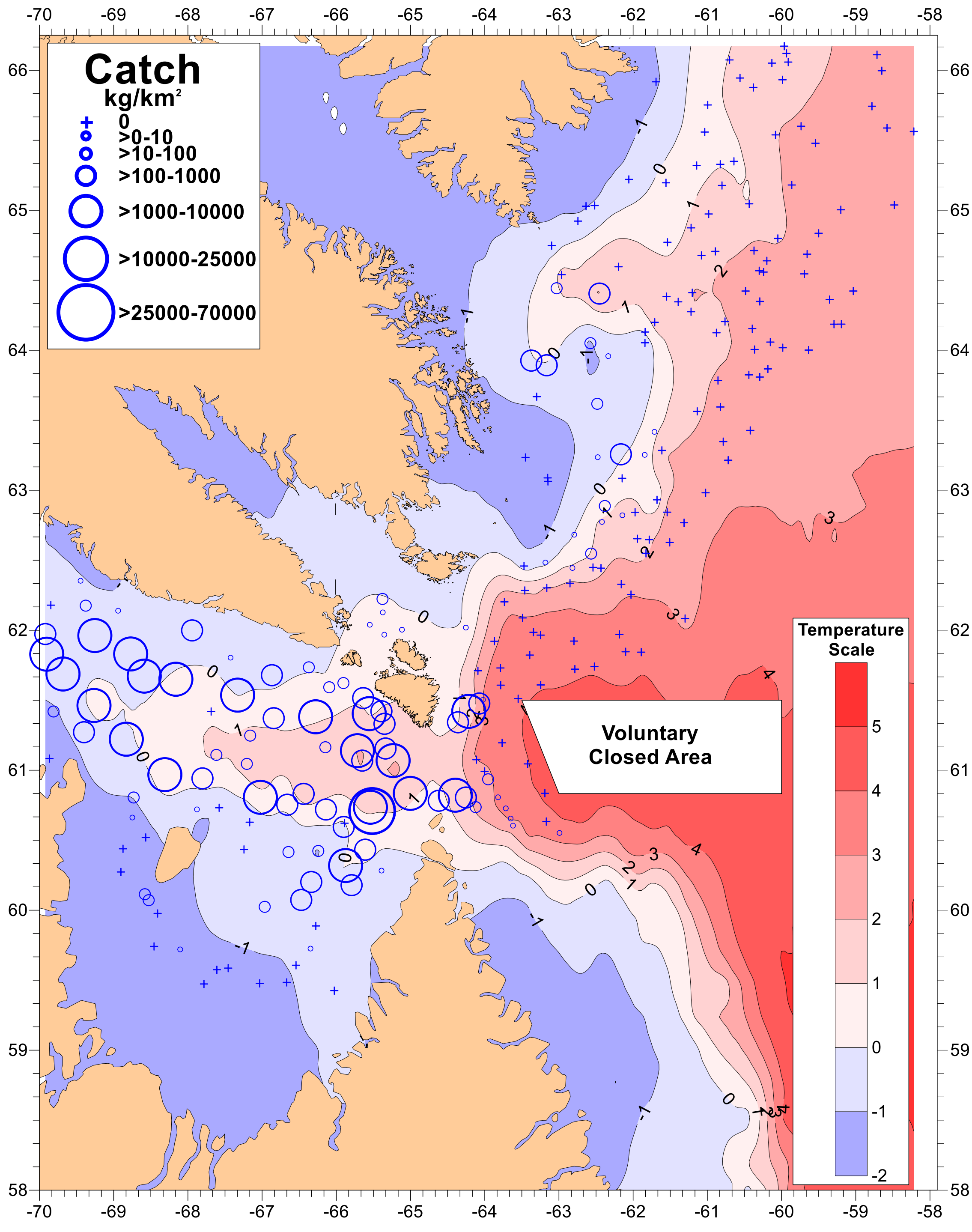

Figure 13. 2016 standardized Pandalus montagui *catch (blue symbols, kg km*$^{-2}$*) in the Eastern and Western Assessment Zones survey overlying the temperature contours observed in the survey areas.*

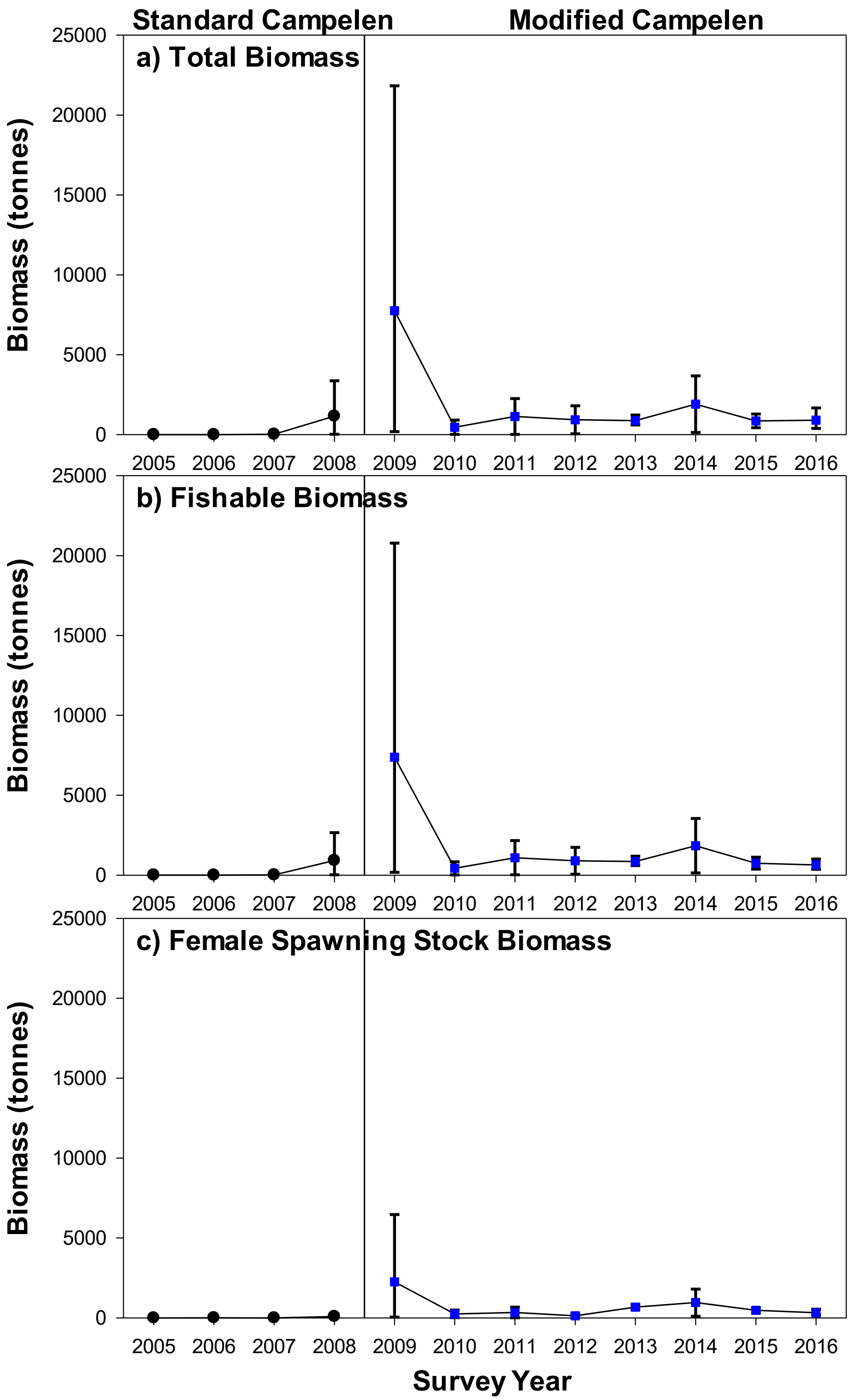

Figure 14. Fishable and female spawning stock biomass indices of Pandalus montagui *in the SFA2EX survey area for the years 2005–2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

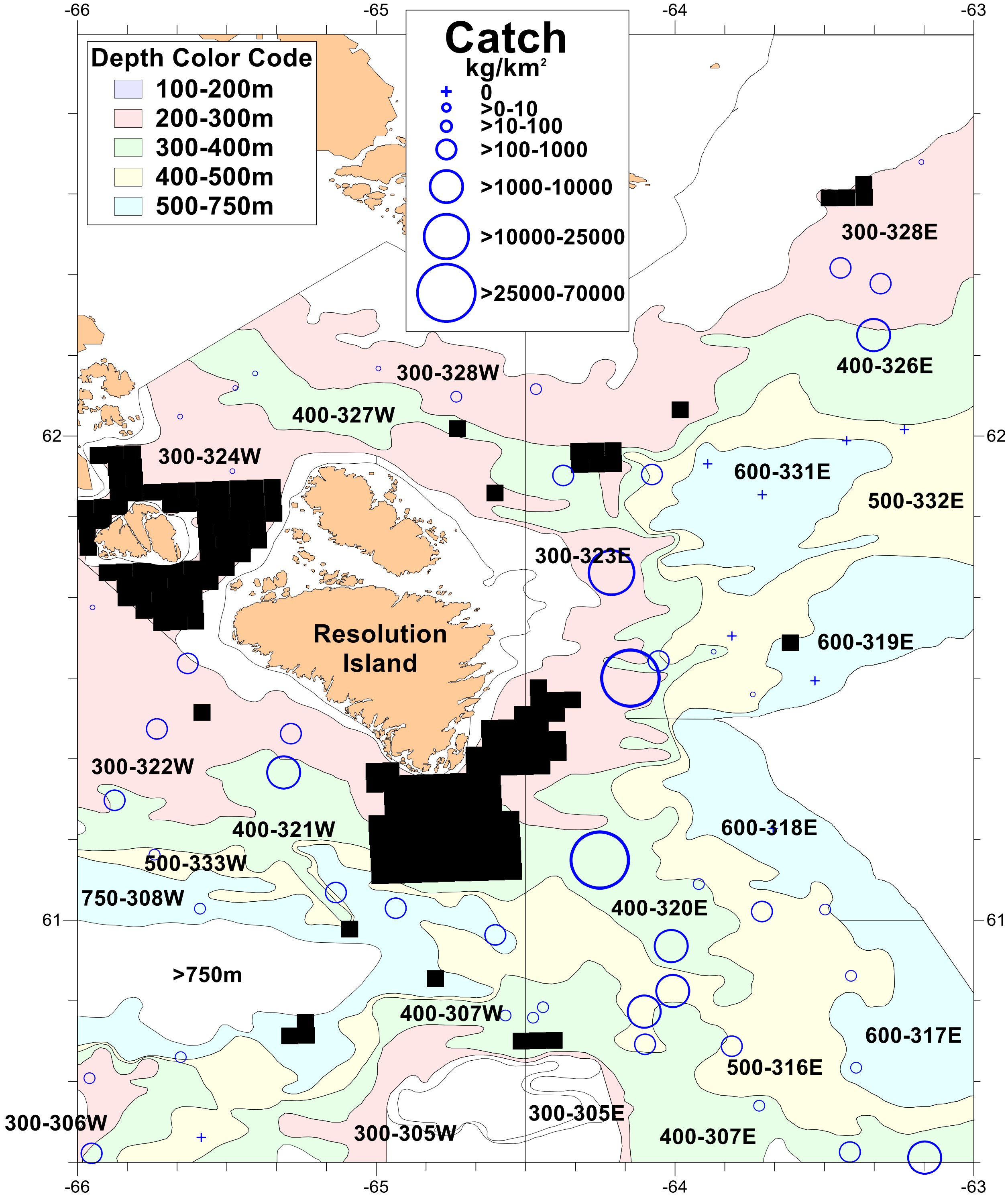

Figure 15. Standardized Pandalus borealis *catch (blue symbols, kg km*$^{-2}$*) from the 2015 RISA survey areas overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

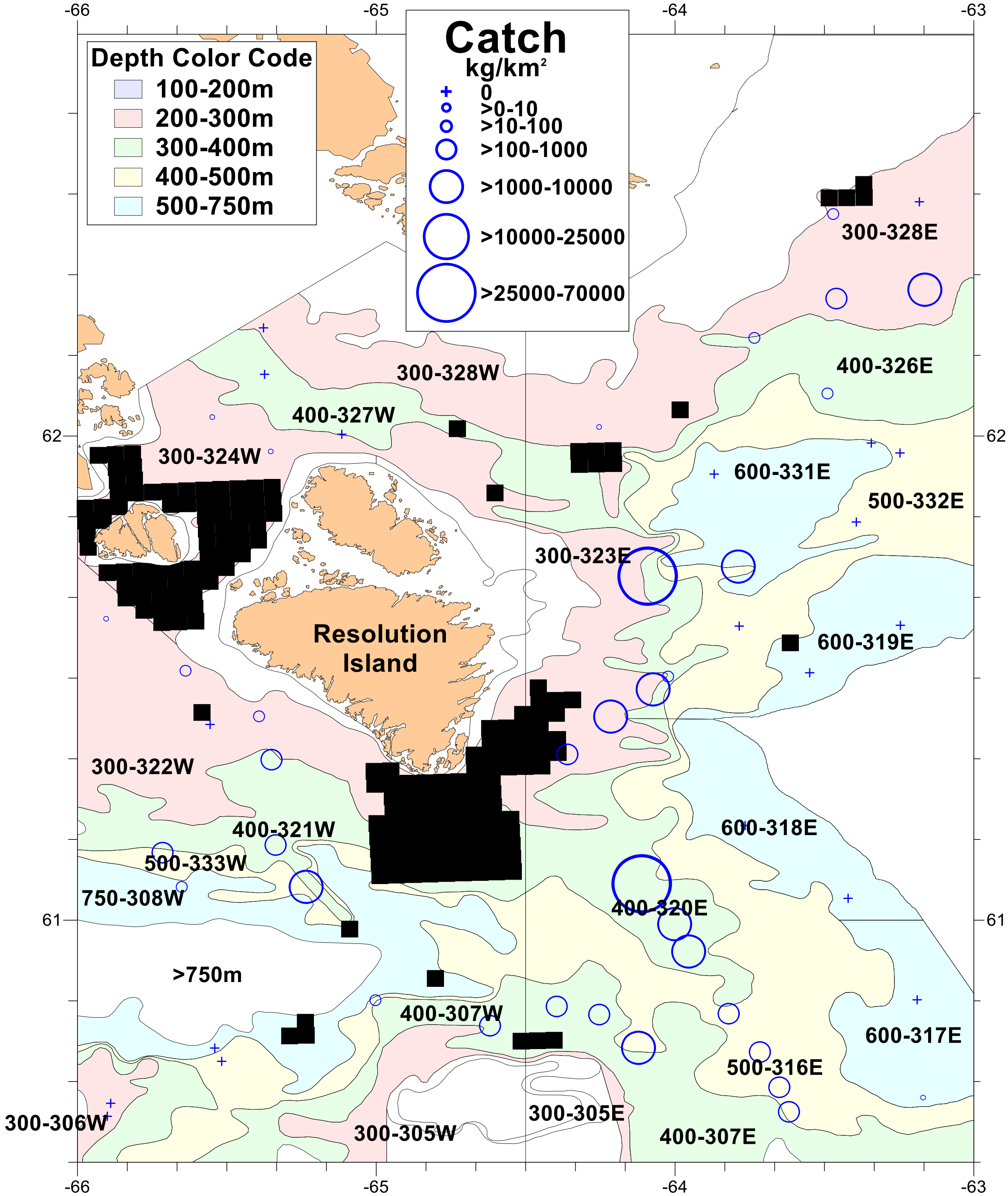

Figure 16. Standardized Pandalus borealis *catch (blue symbols, kg km*$^{-2}$*) from the 2016 RISA survey areas overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

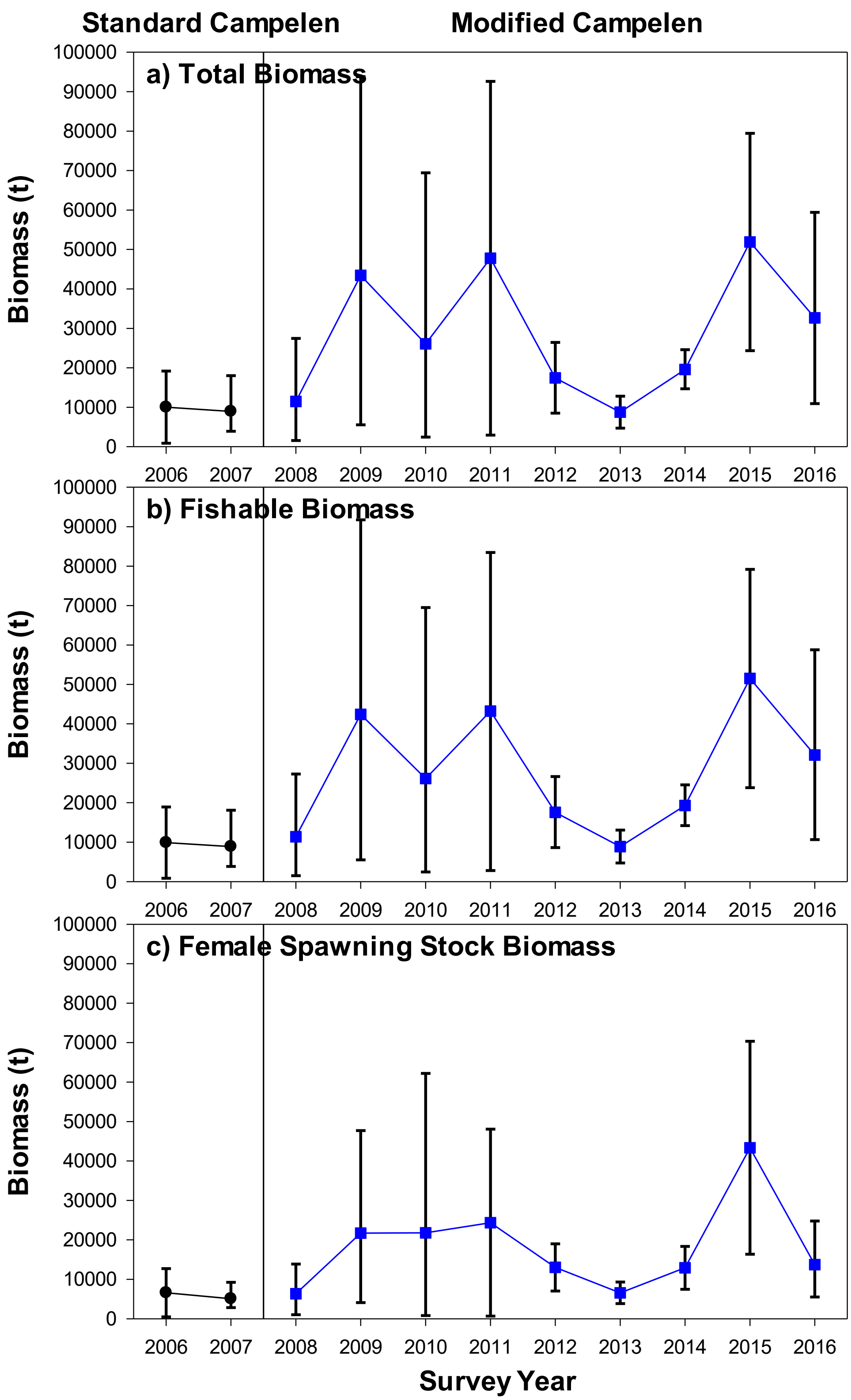

Figure 17. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-East survey area for the years 2006–2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

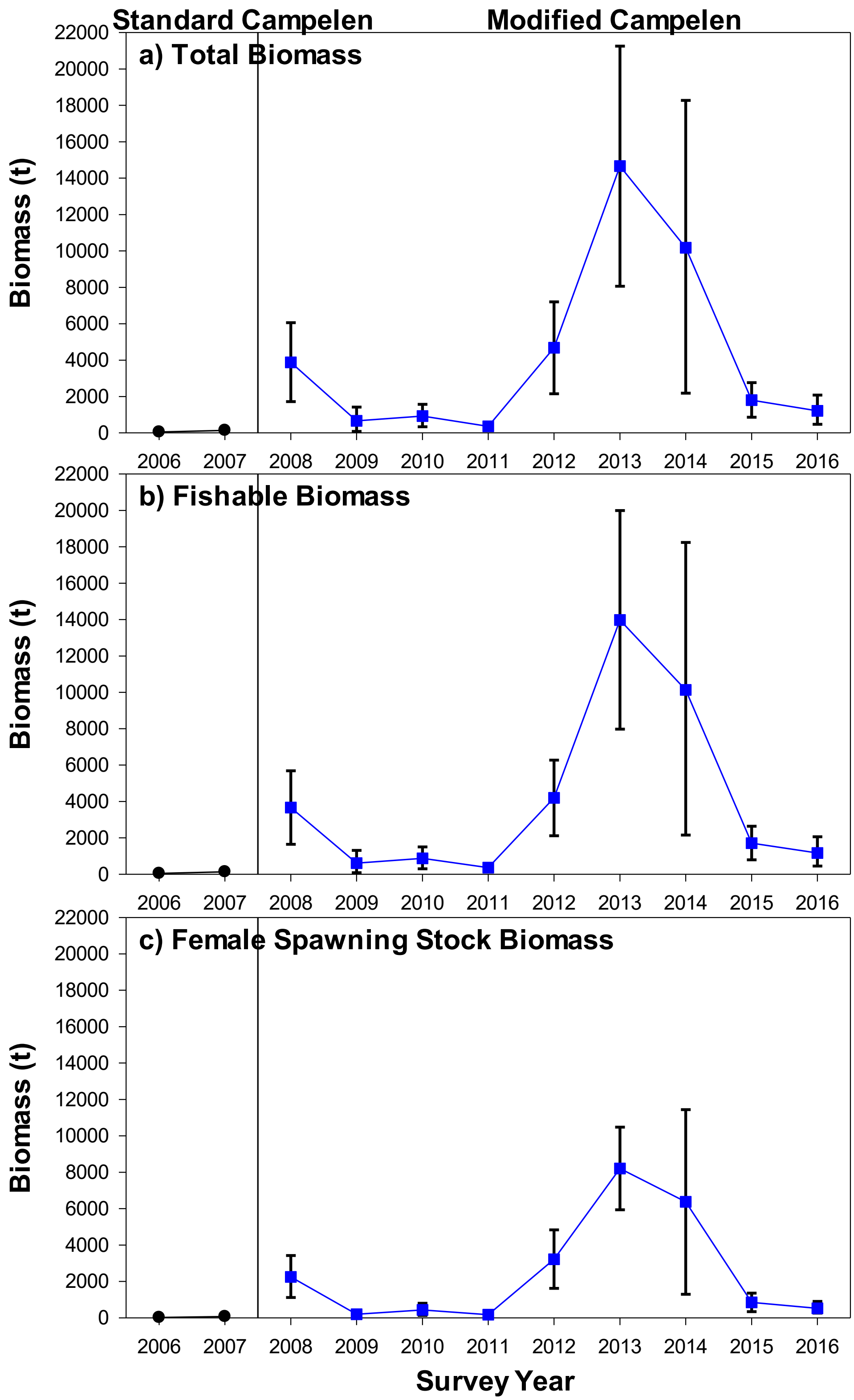

Figure 18. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-West survey area for the years 2006–2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

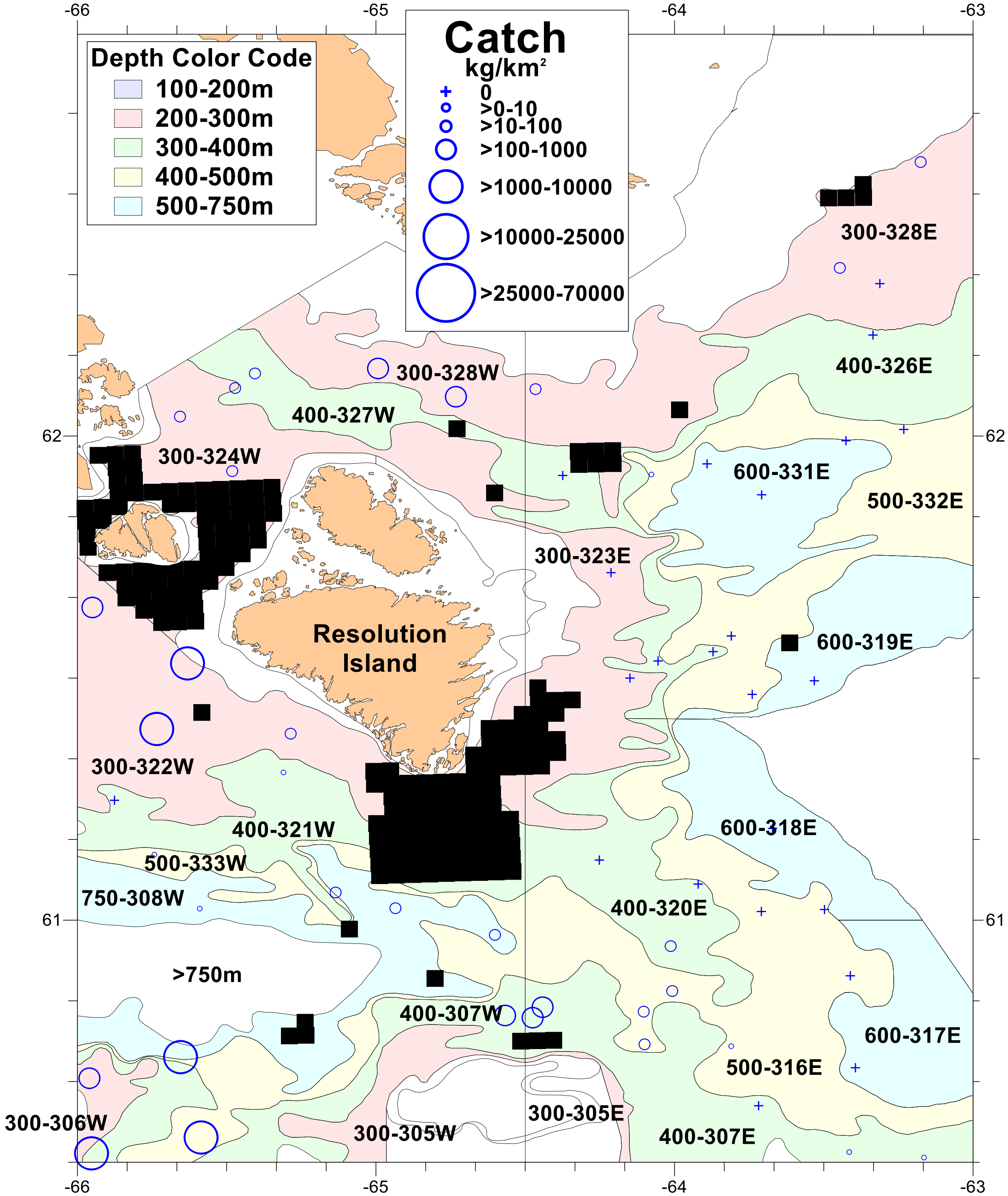

Figure 19. Standardized Pandalus montagui *catch (blue symbols, kg km*$^{-2}$*) from the RISA survey areas in 2015 overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

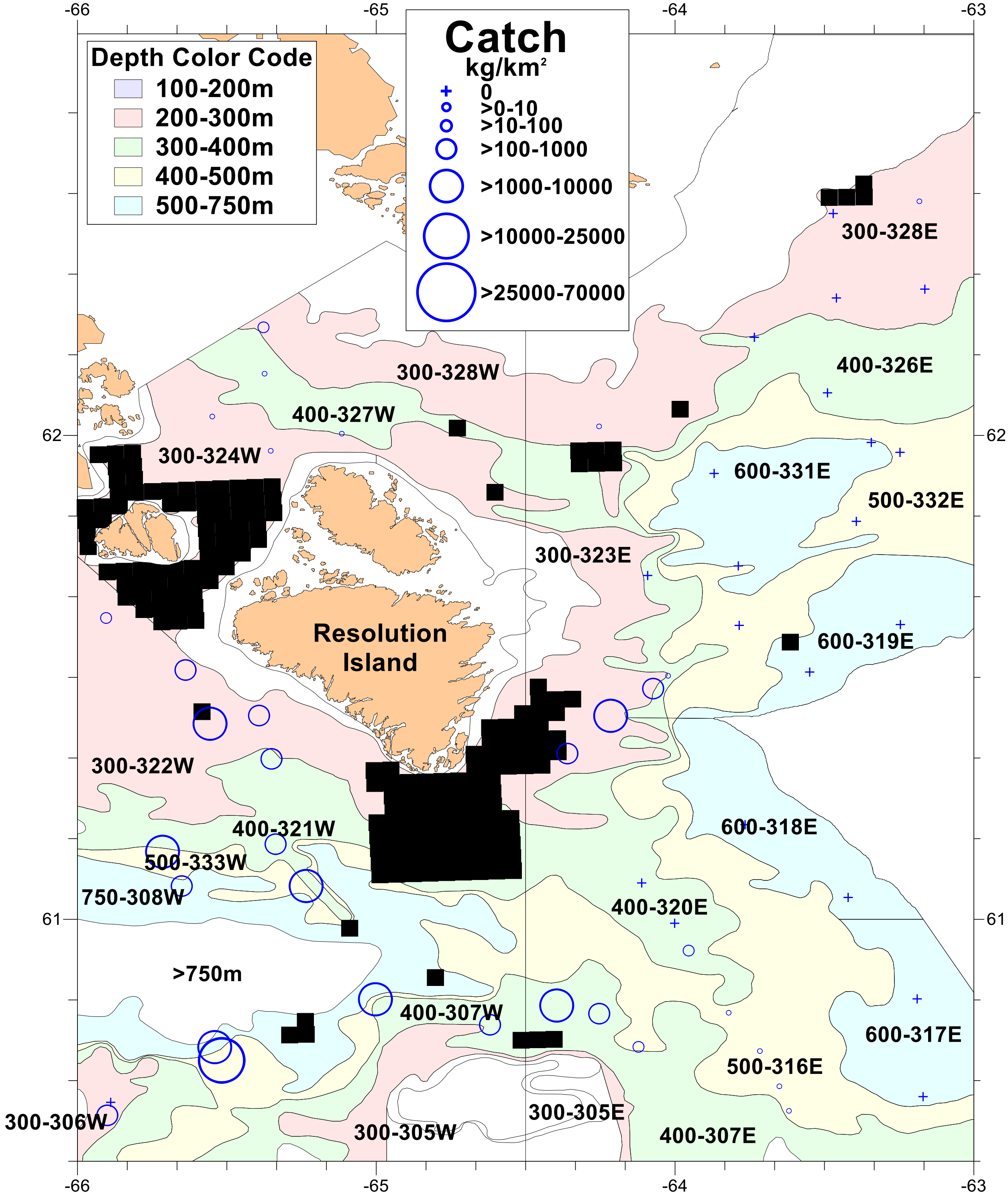

Figure 20. Standardized Pandalus montagui *catch (blue symbols, kg km*$^{-2}$*) from the RISA survey areas in 2016 overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

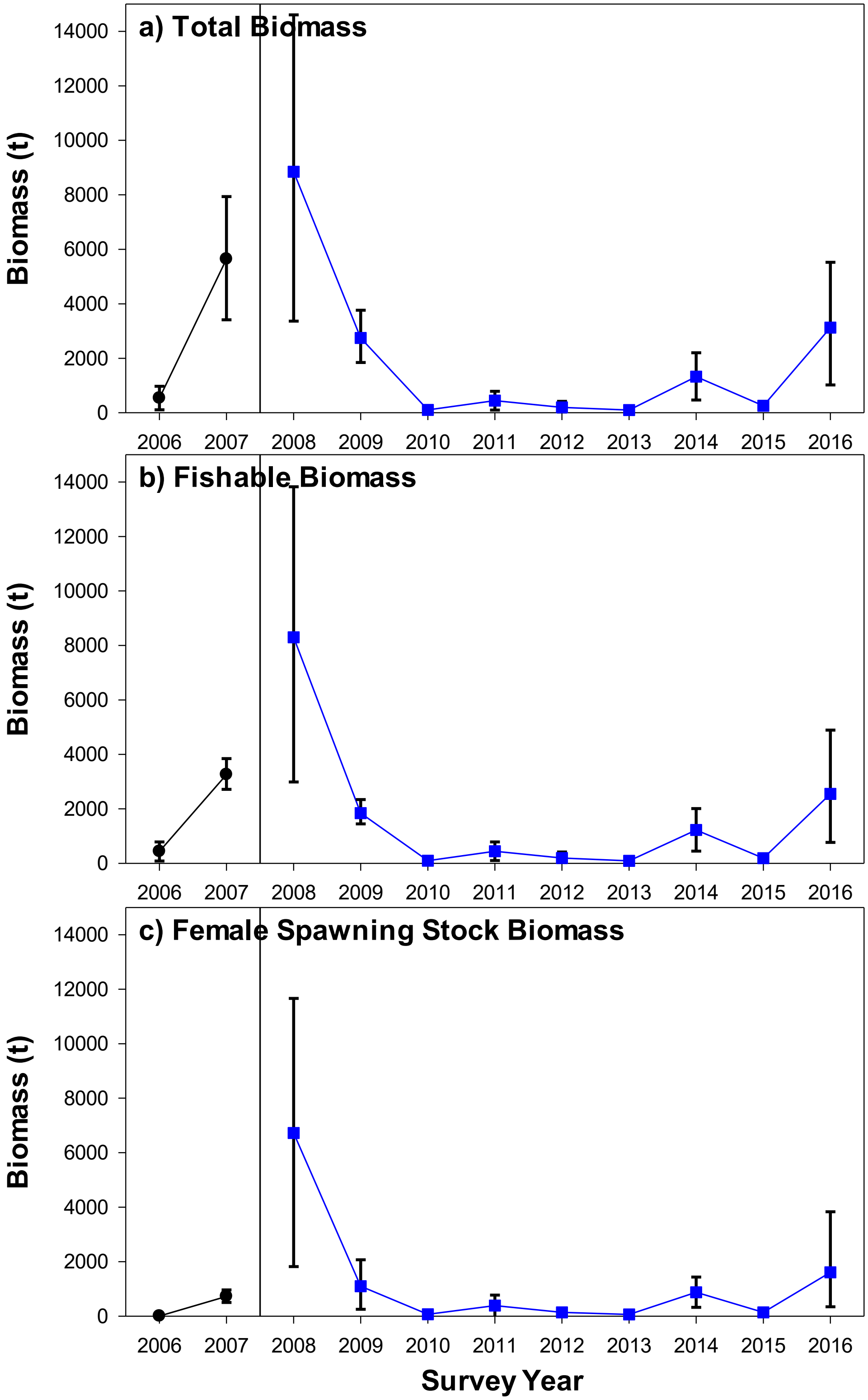

Figure 21. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-East survey areas for the years 2006—2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

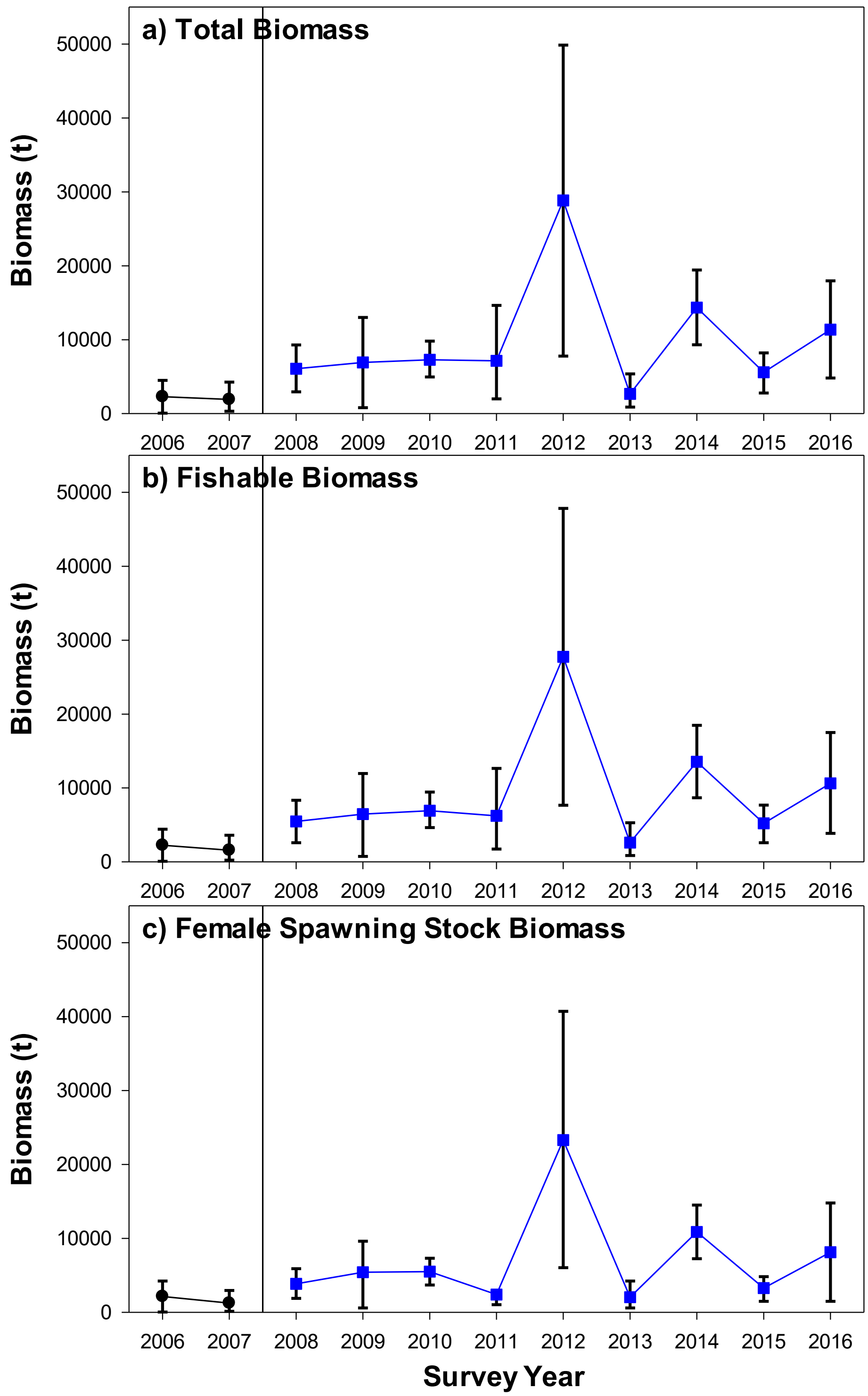

Figure 22. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-West survey areas for the years 2006–2016. Note the change from the standard (black data points) to the modified Campelen trawl (blue data points).*

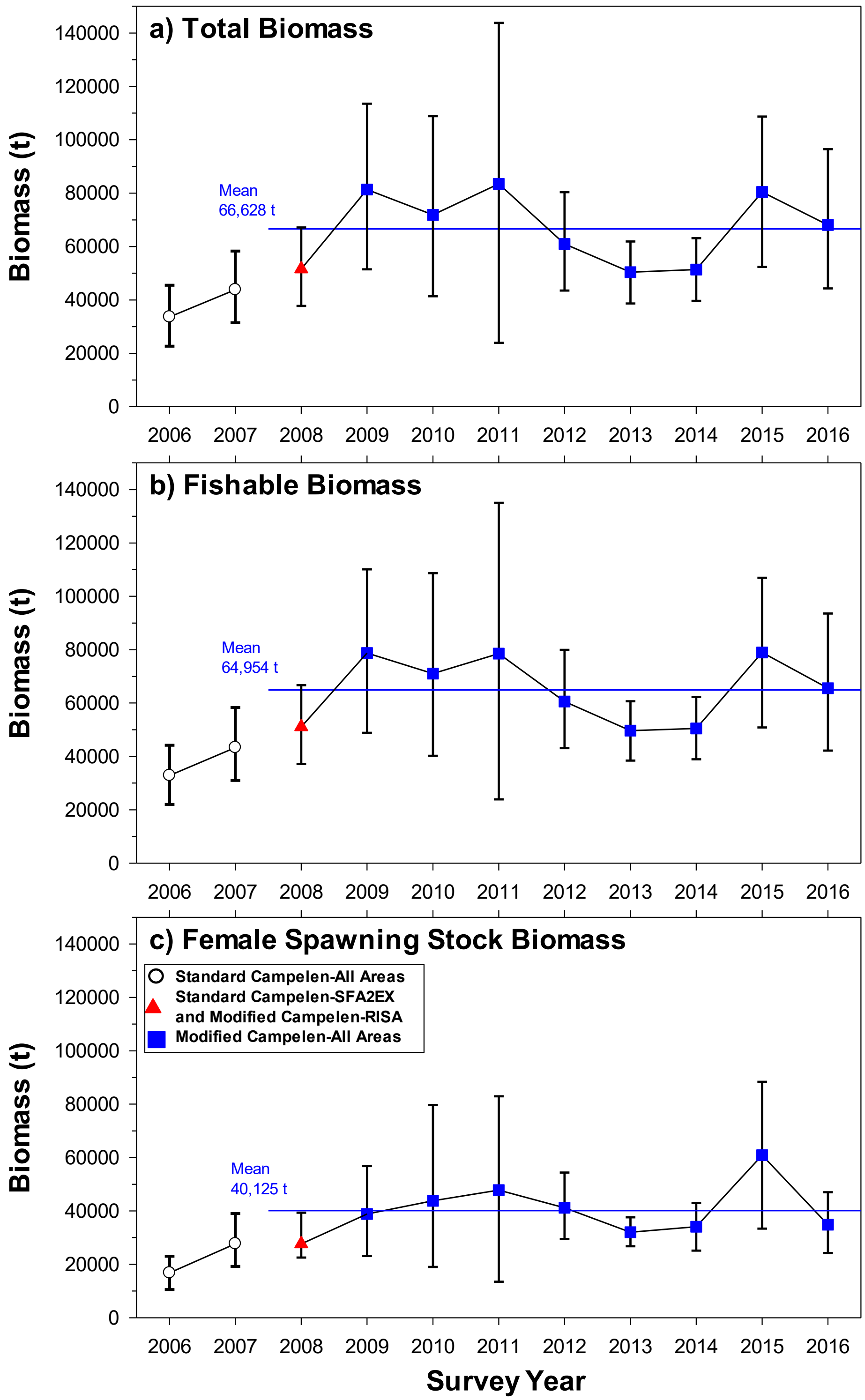

Figure 23. The Eastern Assessment Zone total, fishable and female spawning stock biomass indices (t) of Pandalus borealis *for the survey years 2006–2016. The first two years of survey data (open circles, 2006–2007) are not considered to be comparable with the rest of series because of poor trawl performance around Resolution Island. Survey in 2008/09 (red triangle) completed with standard Campelen and modified Campelen trawls in SFA2EX and RISA, respectively. Horizontal line represents long term mean. Error bars are 95% confidence ranges.*

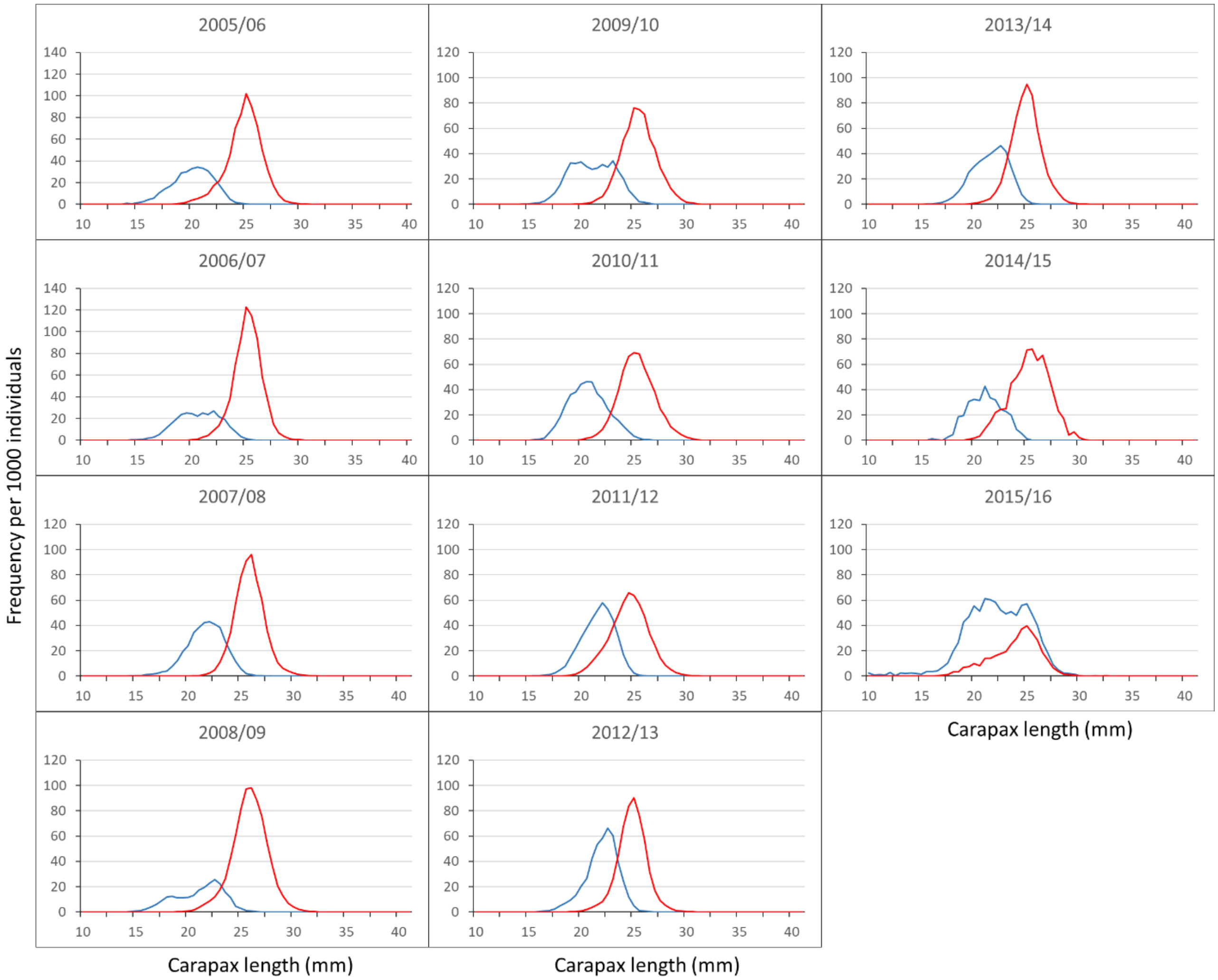

Figure 24. Percent sex composition of Pandalus borealis *in the Eastern Assessment Zone for 2006–2016.*

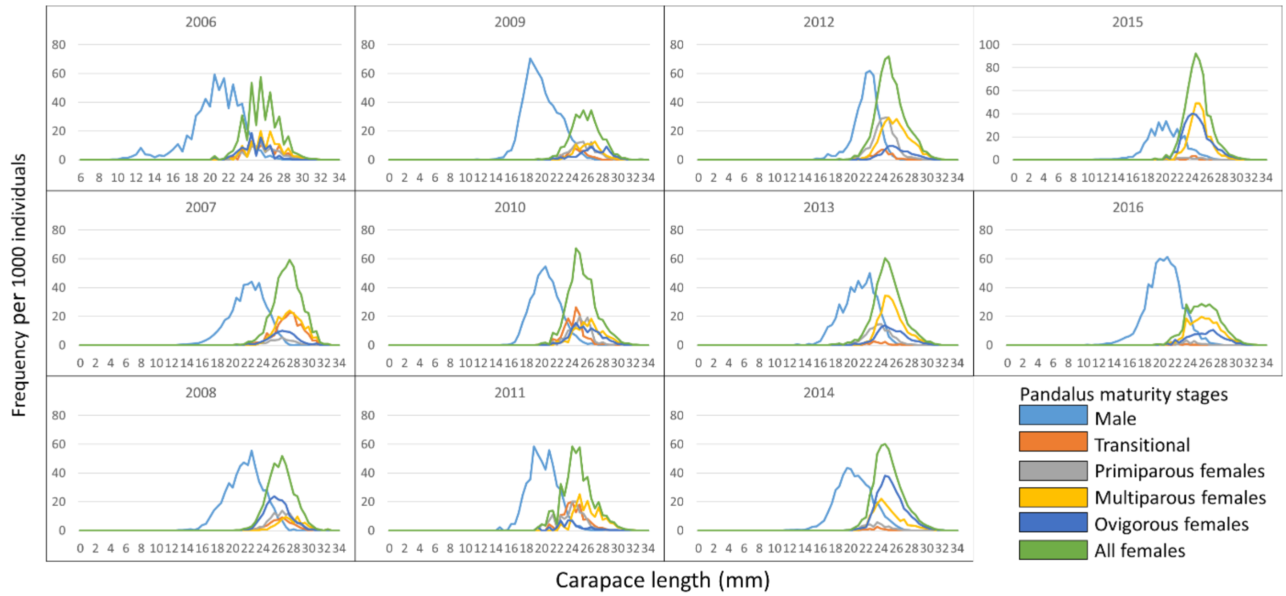

Figure 25. Length frequency curves for all sex maturities of Pandalus borealis *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006–2016.*

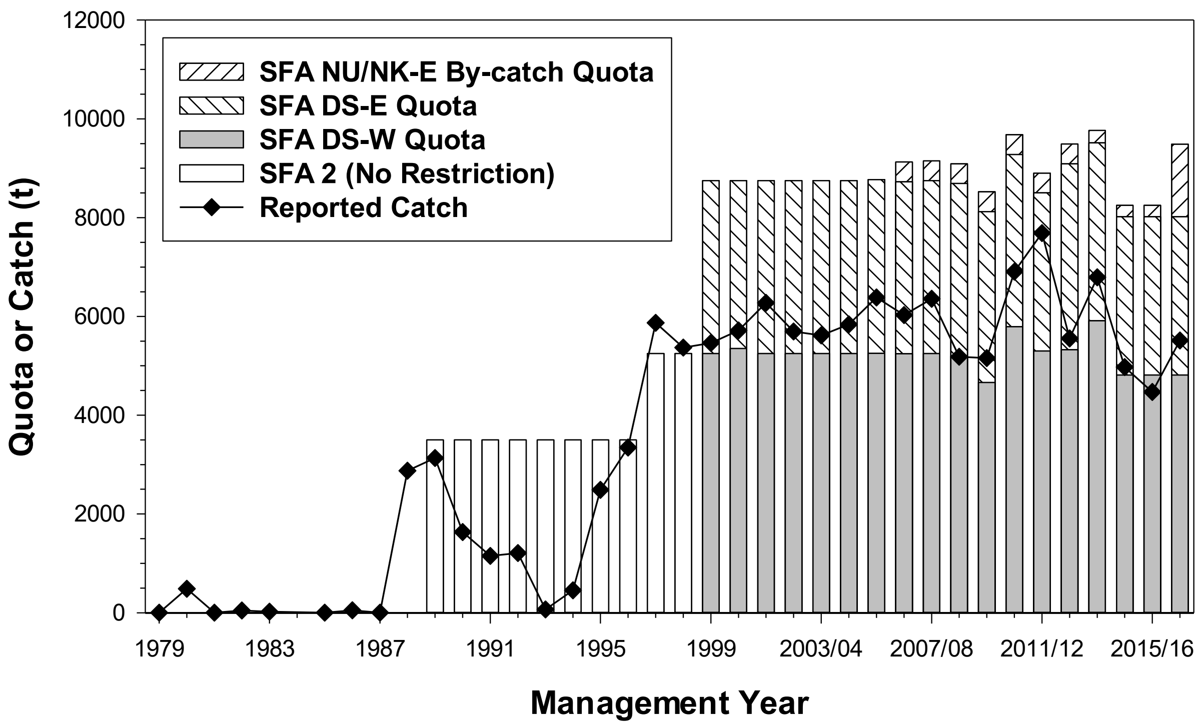

Figure 26. Eastern Assessment Zone Pandalus borealis *TAC (t) and catch (t) reported in the Canadian Atlantic Quota Report. The 2016/17 data are as of 2 February 2017.*

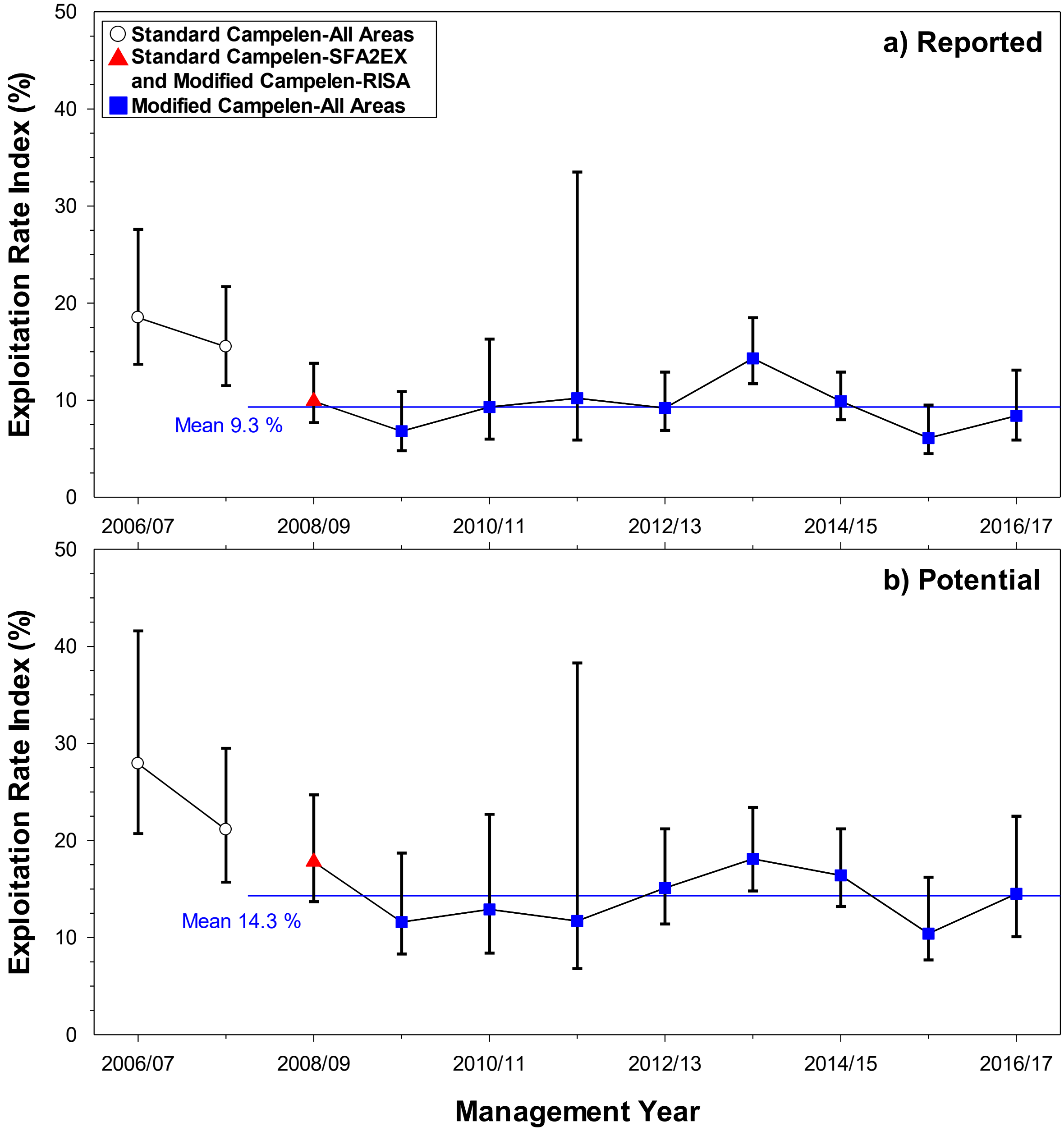

Figure 27. The Eastern Assessment Zone Pandalus borealis *exploitation rate indices for a) the observed rate based on the catch taken and b) the potential rate if the TAC assigned to the zone was taken. The first two years of survey data (open circles, 2006–2007) are not considered to be comparable with the rest of series because of poor trawl performance around Resolution Island. Survey in 2008/09 (red triangle) completed with standard Campelen and modified Campelen trawls in SFA2EX and RISA, respectively. Remaining data points (blue squares) completed with a Modified Campelen trawl. Horizontal line represents long term mean. Error bars are 95% confidence ranges.*

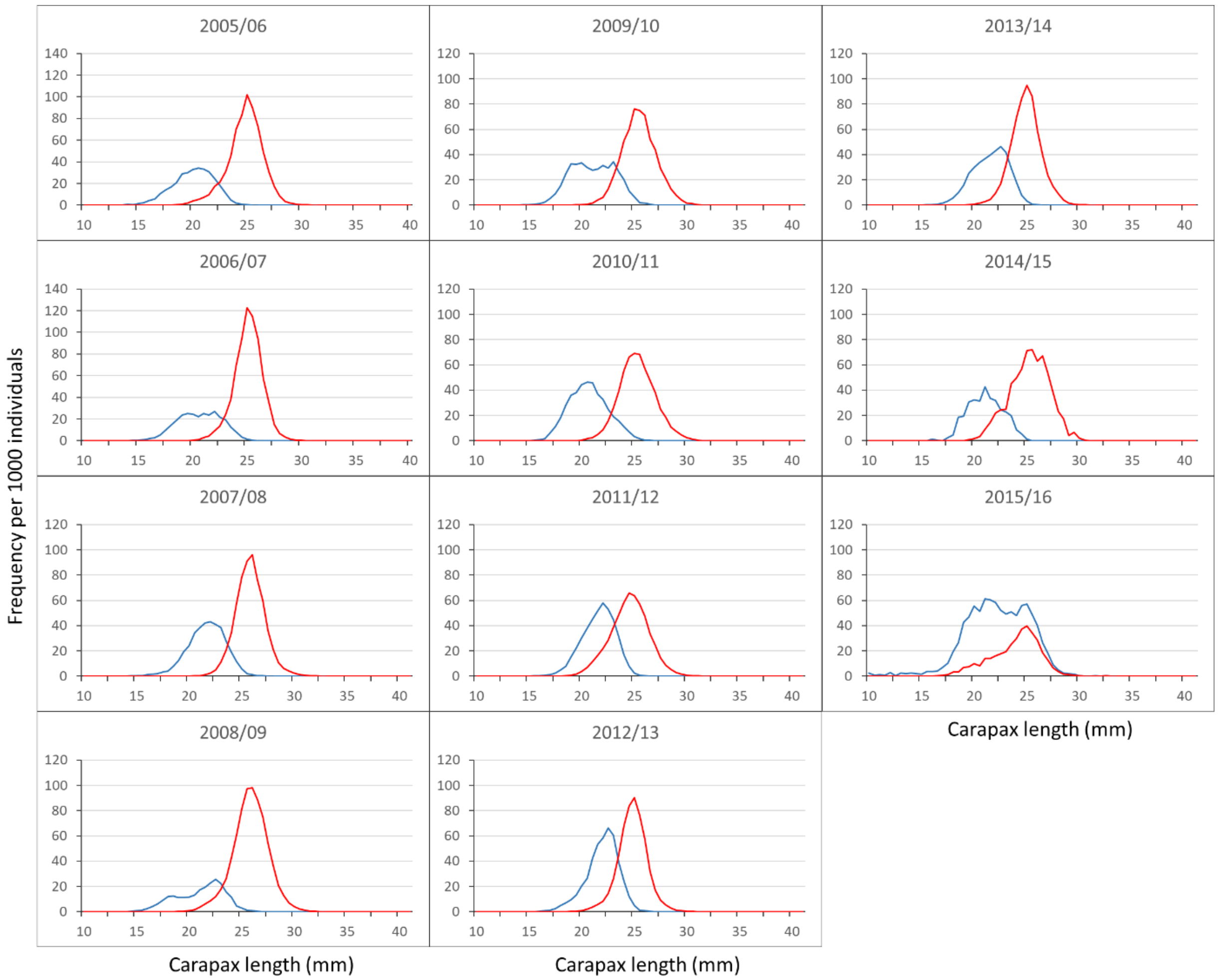

Figure 28. Length frequency of the commercial catch of male (blue line) and female (red line) Pandalus borealis *in the Eastern Assessment Zone over the management years 2005/06 through 2016/17.*

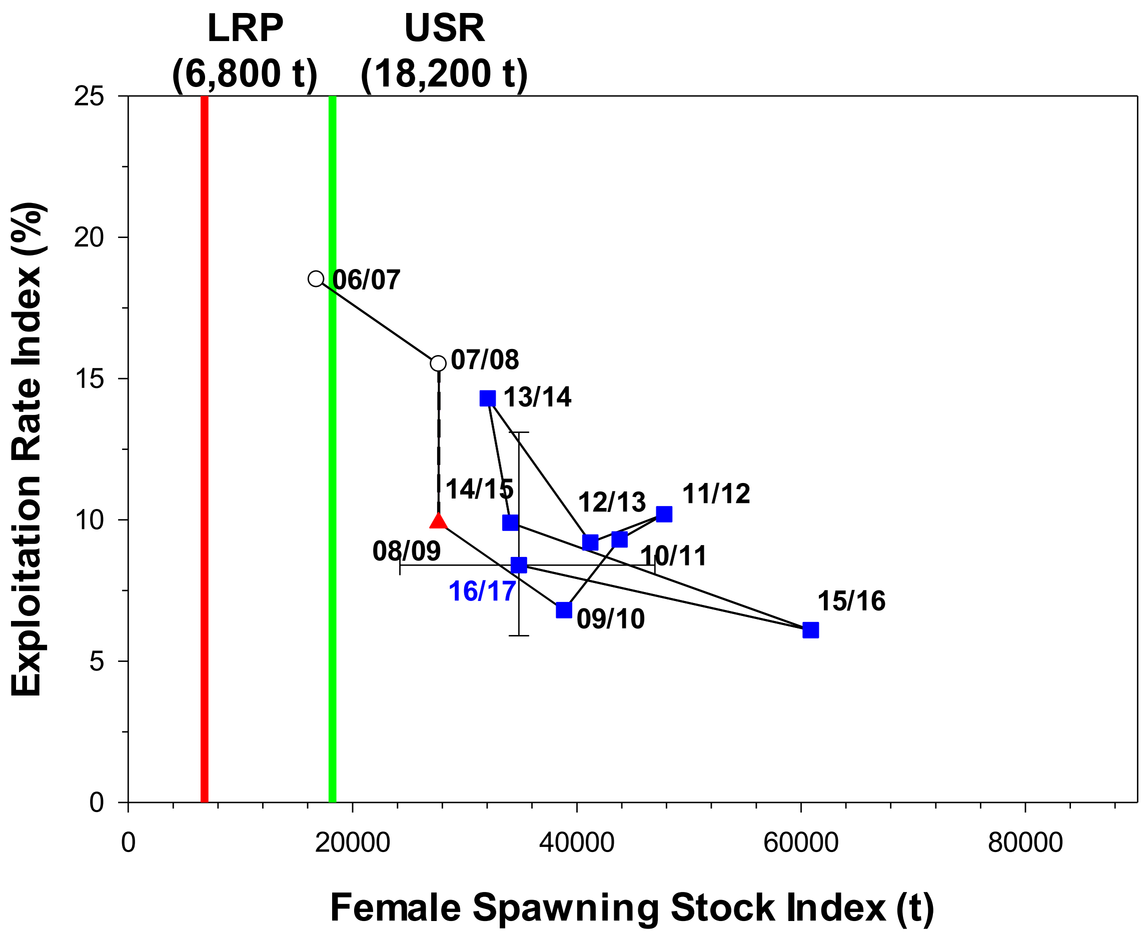

Figure 29. The Eastern Assessment Zone trajectory of Pandalus borealis *female spawning stock biomass and exploitation rate indices in relation to its reference points. USR = Upper stock reference (green vertical line) and LRP = limit reference point (red vertical line) are 80% and 30%, respectively, of the geometric mean of the SSB index (2006–2008 in SFA 2). Error bars are 95% confidence ranges. White circles represent data collected with a Standard Campelen trawl, red triangle represents a year when stock was assessed with a Standard Campelen trawl in SFA 2EX and with a Modified Campelen in RISA, blue squares represent data collected with Modified Campelen trawl throughout the entire assessment area.*

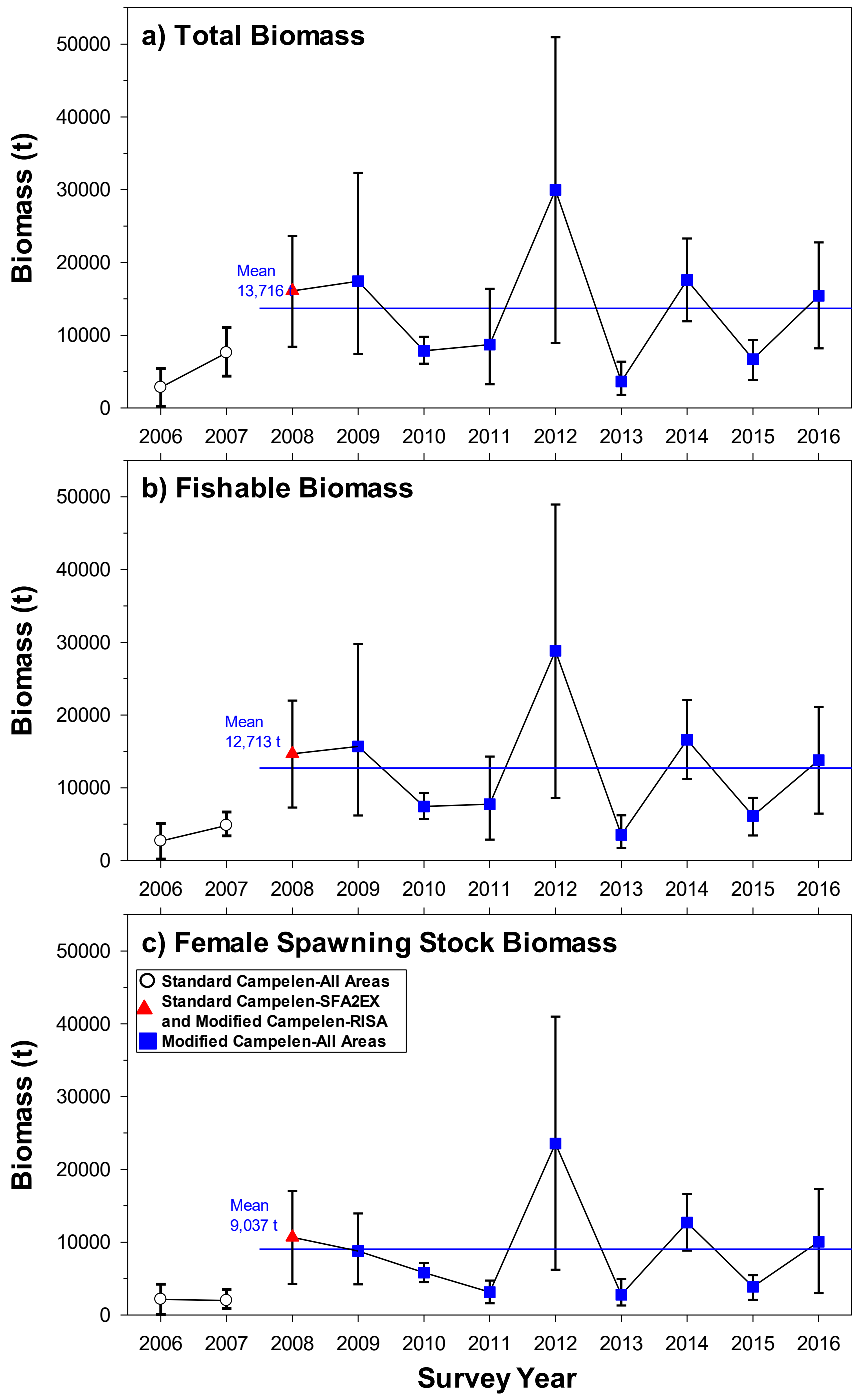

Figure 30. The Eastern Assessment Zone Pandalus montagui *total, fishable and female spawning stock biomass indices for the survey years 2006–2016. The first two years of survey data (open circles, 2006–2007) are not considered to be comparable with the rest of series because of poor trawl performance around Resolution Island. Survey in 2008/09 (red triangle) completed with standard Campelen and modified Campelen trawls in SFA2 EX and RISA, respectively. Remaining data points (blue squares) completed with a Modified Campelen trawl. Horizontal line represents long term mean. Error bars are 95% confidence ranges.*

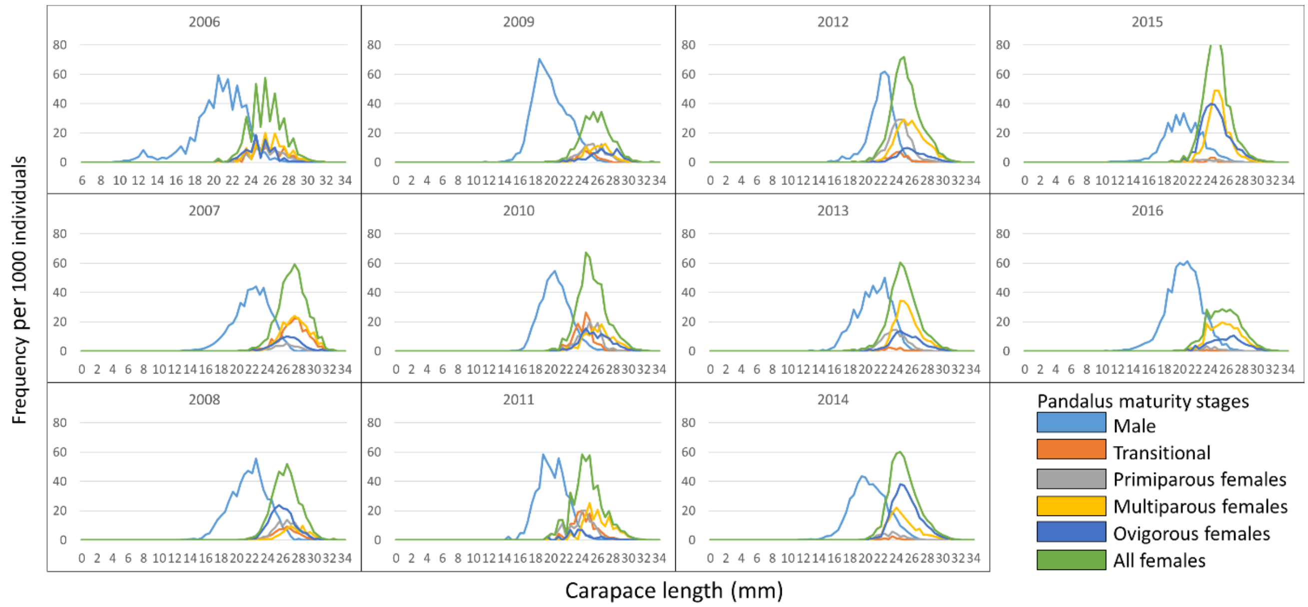

Figure 31. Length frequency curves for all sex maturities of Pandalus montagui *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006–2016.*

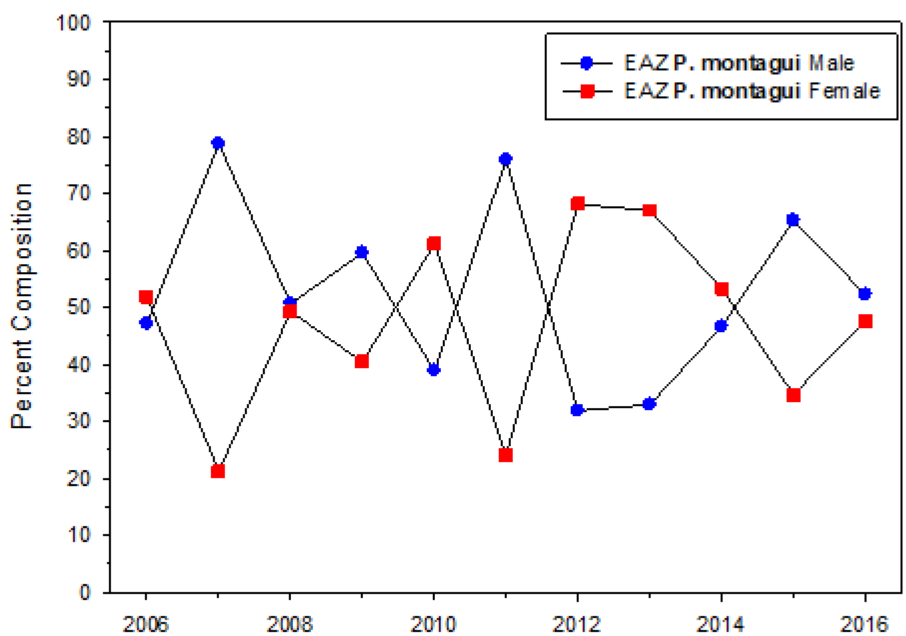

Figure 32. Percent sex composition of Pandalus montagui *in the Eastern Assessment Zone for 2006–2016.*

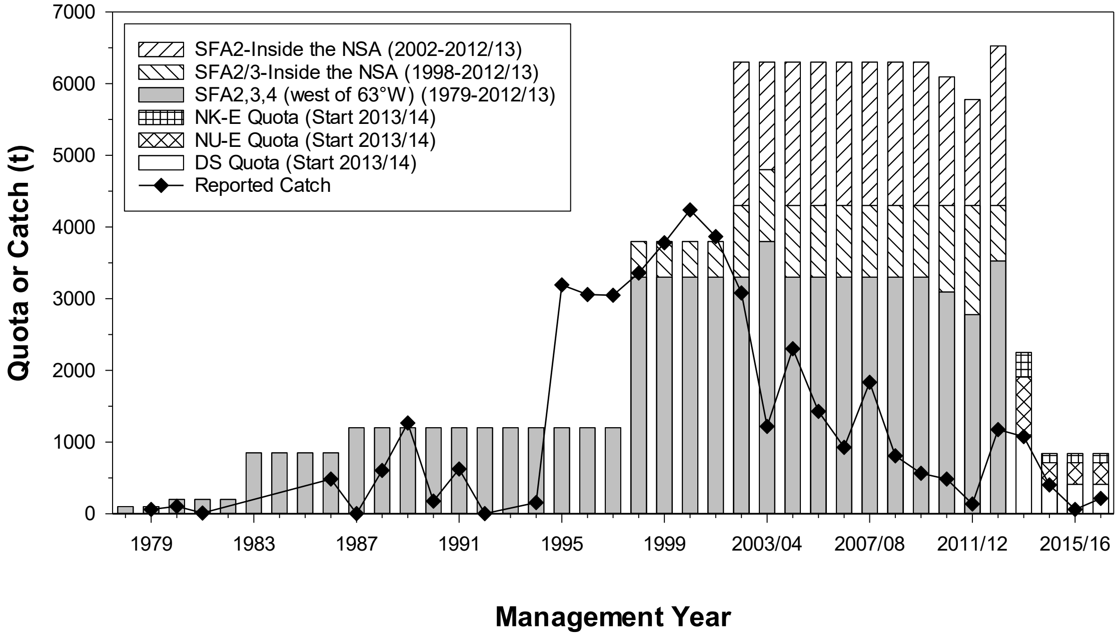

Figure 33. Eastern Assessment Zone Pandalus montagui *TAC and catch reported in the Canadian Atlantic Quota Report (CAQR). The 2016/17 data are as of 2 February 2017.*

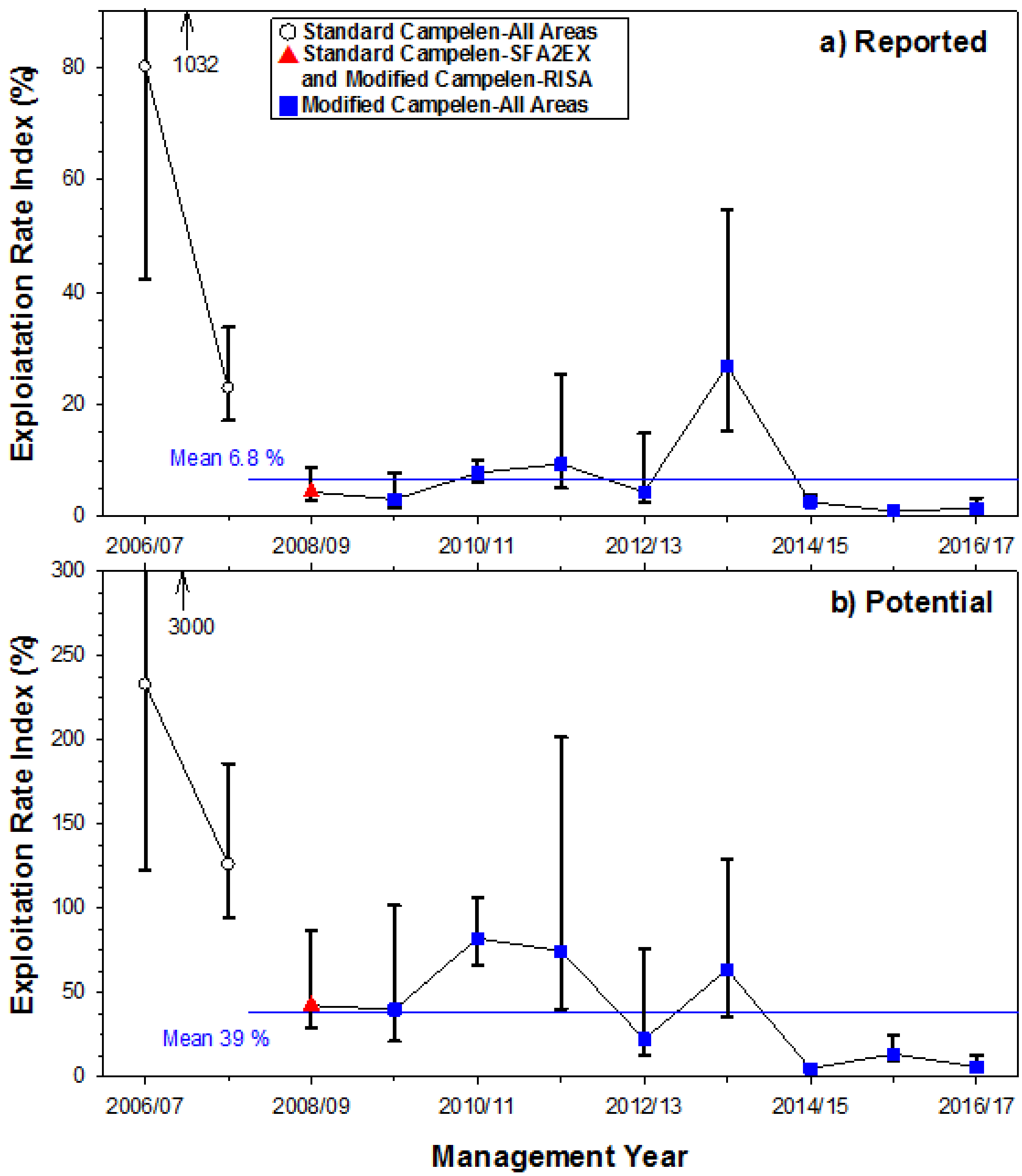

Figure 34. The Eastern Assessment Zone Pandalus montagui *exploitation rate indices for a) the reported rate, based on the catch taken and b) the potential rate if the TAC was taken. Horizontal line represents long term mean. Error bars are 95% confidence ranges. Upper confidence limit for 2006/07 is shown numerically. White circles represent data collected with a Standard Campelen trawl, red triangle represents a year when stock was assessed with a Standard Campelen trawl in SFA 2EX and with a Modified Campelen in RISA, blue squares represent data collected with Modified Campelen trawl throughout the entire assessment area.*

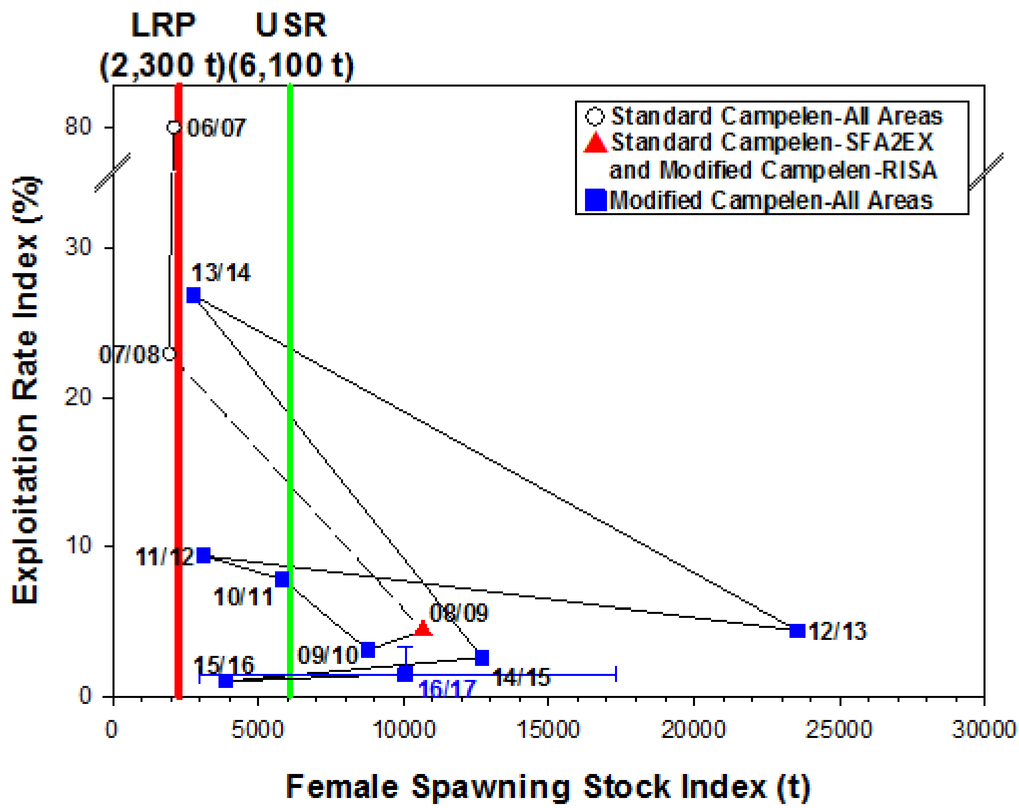

Figure 35. The Eastern Assessment Zone trajectory of Pandalus montagui *female spawning stock biomass and exploitation rate indices in relation to its reference points. USR = Upper stock reference (green vertical line) and LRP = limit reference point (red vertical line) are 80% and 30%, respectively, of the geometric mean of the SSB index (2006–2008 in SFA 2). Error bars are 95% confidence ranges. White circles represent data collected with a Standard Campelen trawl, red triangle represents a year when stock was assessed with a Standard Campelen trawl in SFA 2EX and with a Modified Campelen in RISA, blue squares represent data collected with Modified Campelen trawl throughout the entire assessment area.*

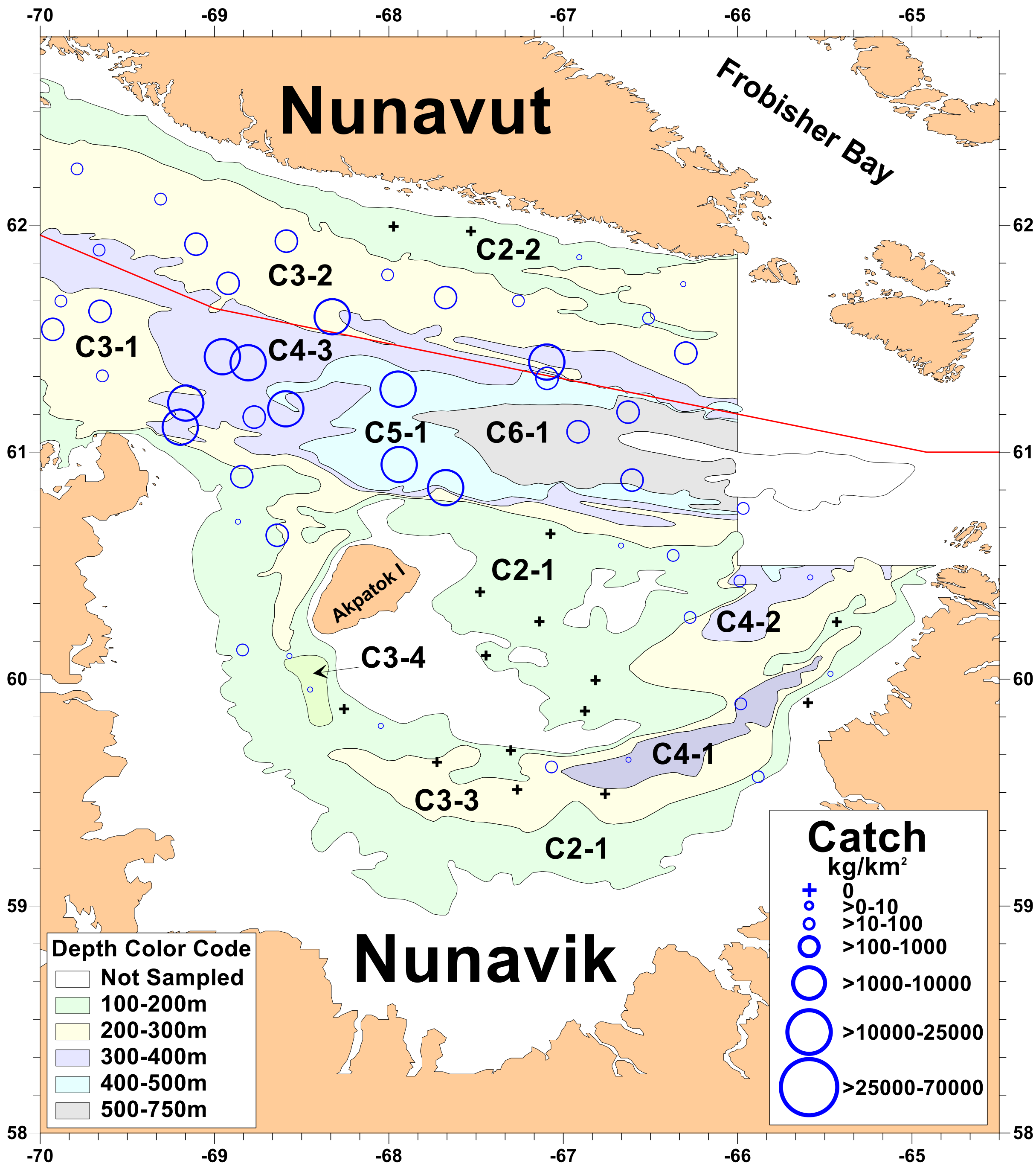

Figure 36. Standardized Pandalus borealis *catch from the 2015 Western Assessment Zone survey overlying the depth contours and strata of the survey area.*

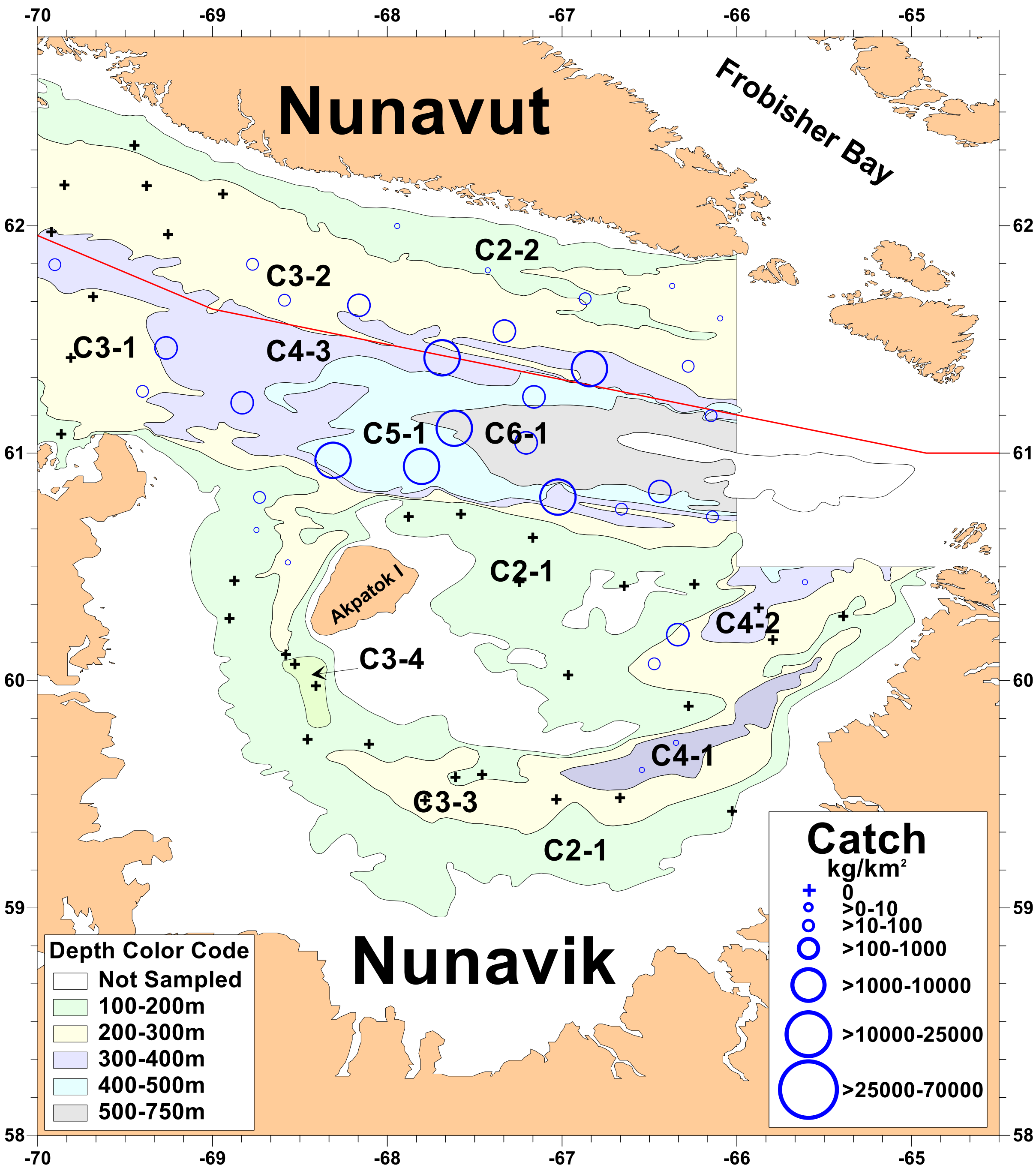

Figure 37. Standardized Pandalus borealis *catch from the 2016 Western Assessment Zone survey overlying the depth contours and strata of the survey area.*

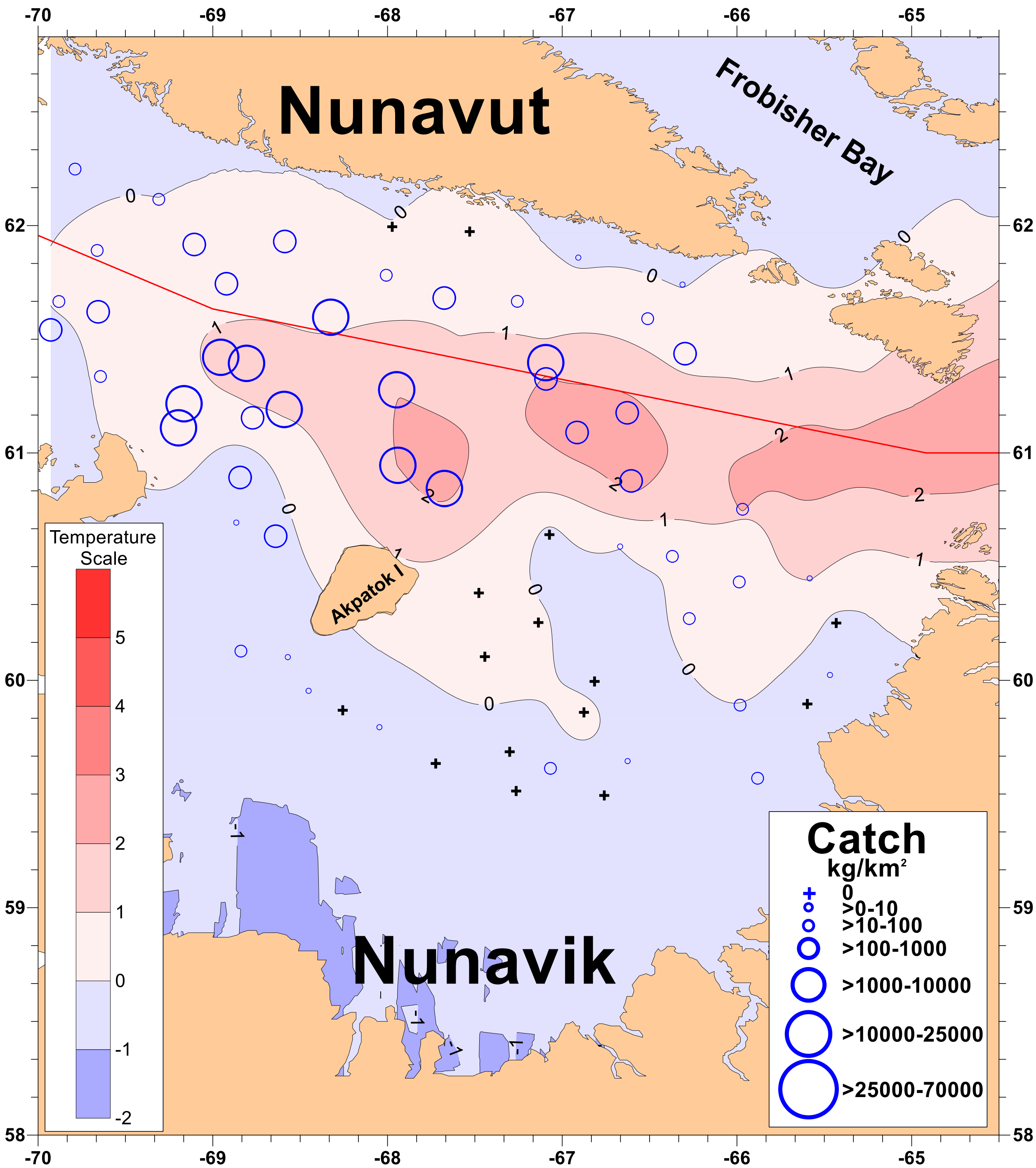

Figure 38. 2015 standardized Pandalus borealis *catch in the Western Assessment Zones survey overlying the temperature contours observed in the survey areas.*

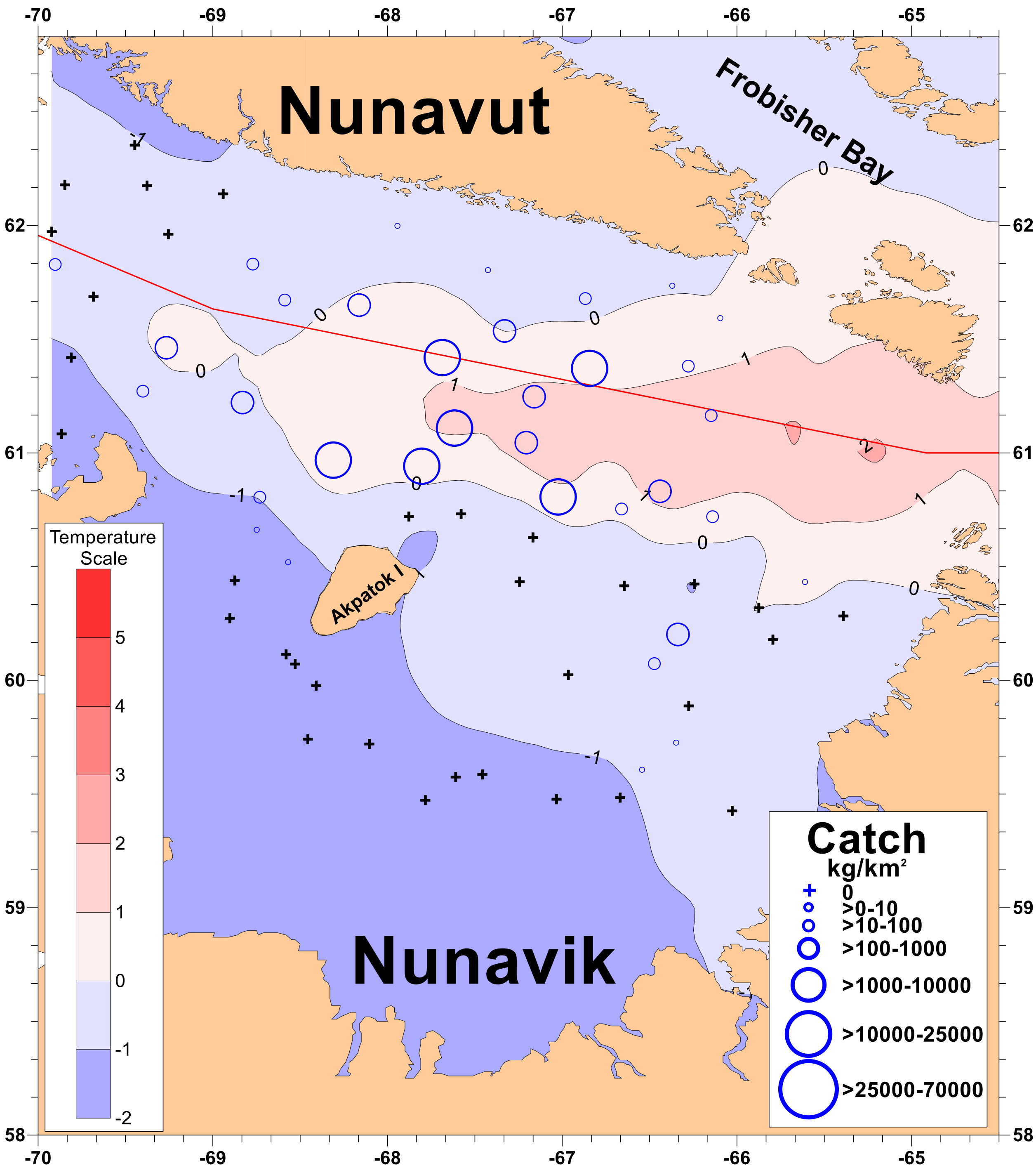

Figure 39. 2016 standardized Pandalus borealis *catch in the Western Assessment Zones survey overlying the temperature contours observed in the survey areas.*

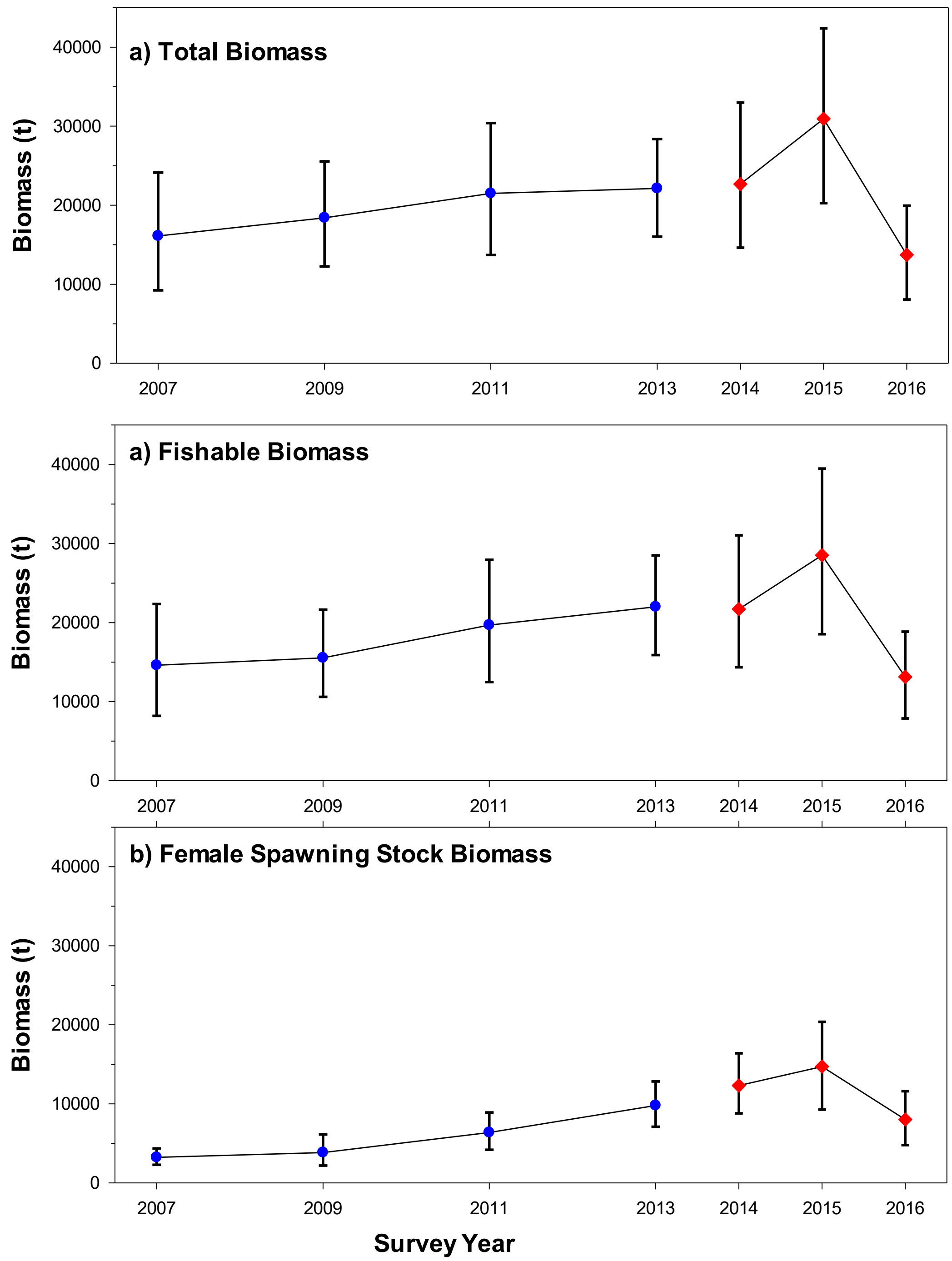

Figure 40. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the Western Assessment Zone. In 2007, 2009, 2011 and 2013 the survey was led by DFO (blue dots), while between 2014 and 2016 the area was surveyed by DFO-NSRF (red diamonds).*

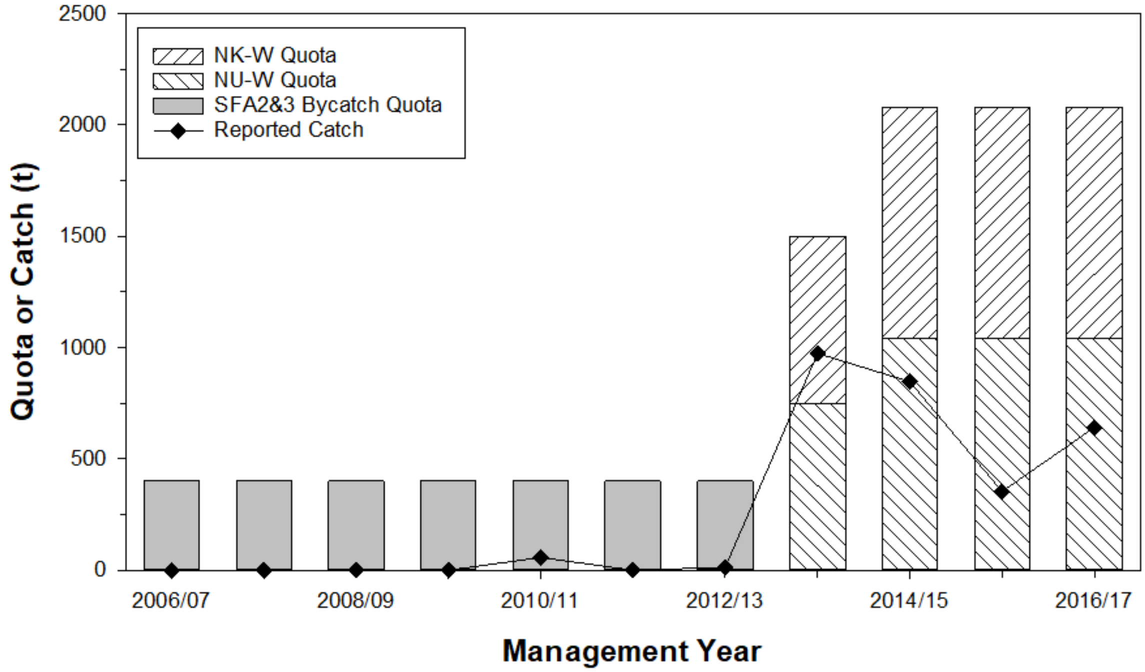

Figure 41. The Western Assessment Zone Pandalus borealis *TAC and catch recorded in the Canadian Atlantic Quota Report (CAQR) for 2014/15 and observer records prior to 2013/14. Catch records from CAQR as of 2 February 2017.*

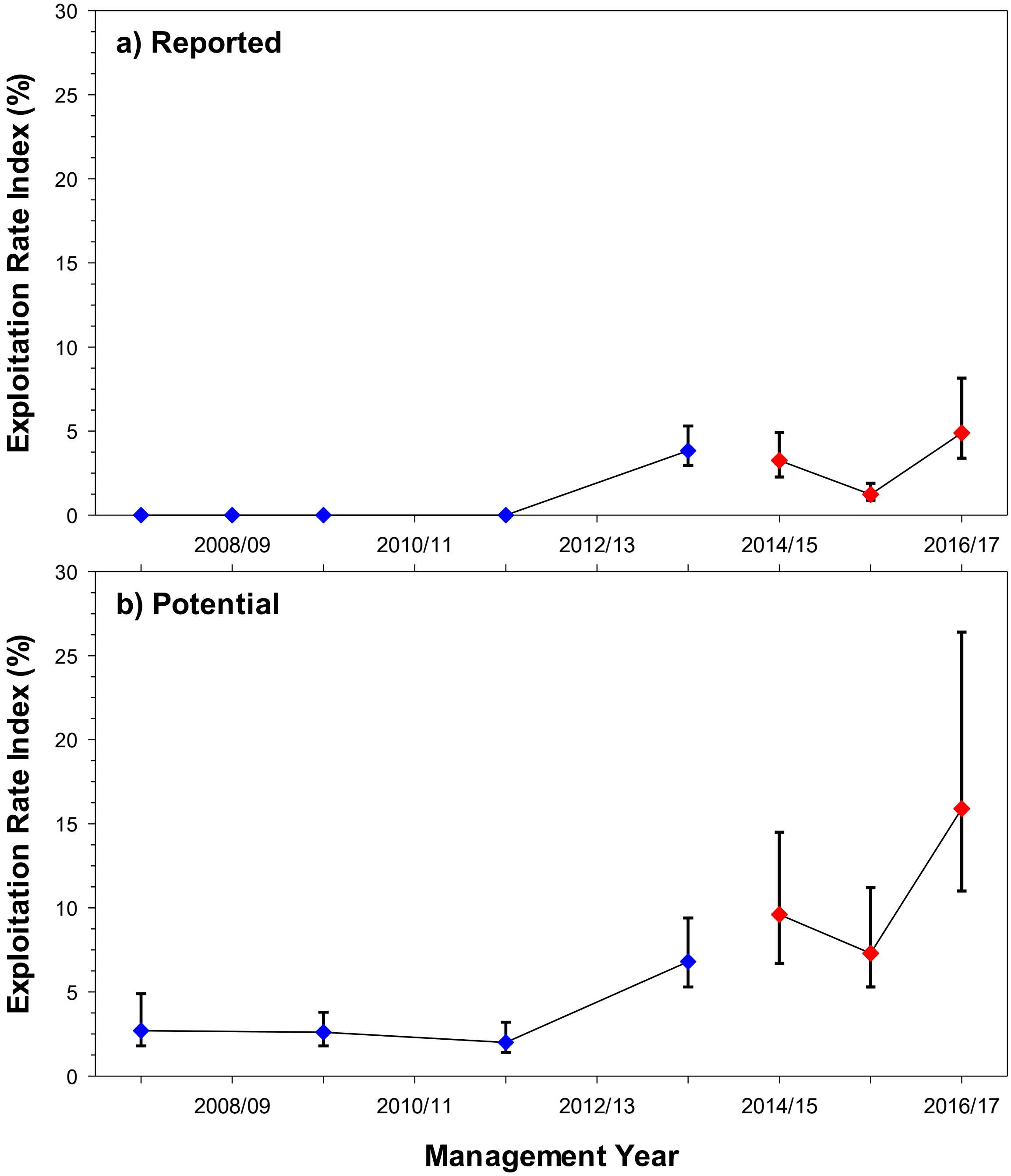

Figure 42. The a) reported and b) potential Western Assessment Zone Pandalus borealis *exploitation rate index. The DFO survey (blue diamonds) is not directly comparable with the 2014 survey (red diamond) conducted by the DFO-NSRF. 2014/15 represents the start of a new time series. Error bars represent 95% confidence range.*

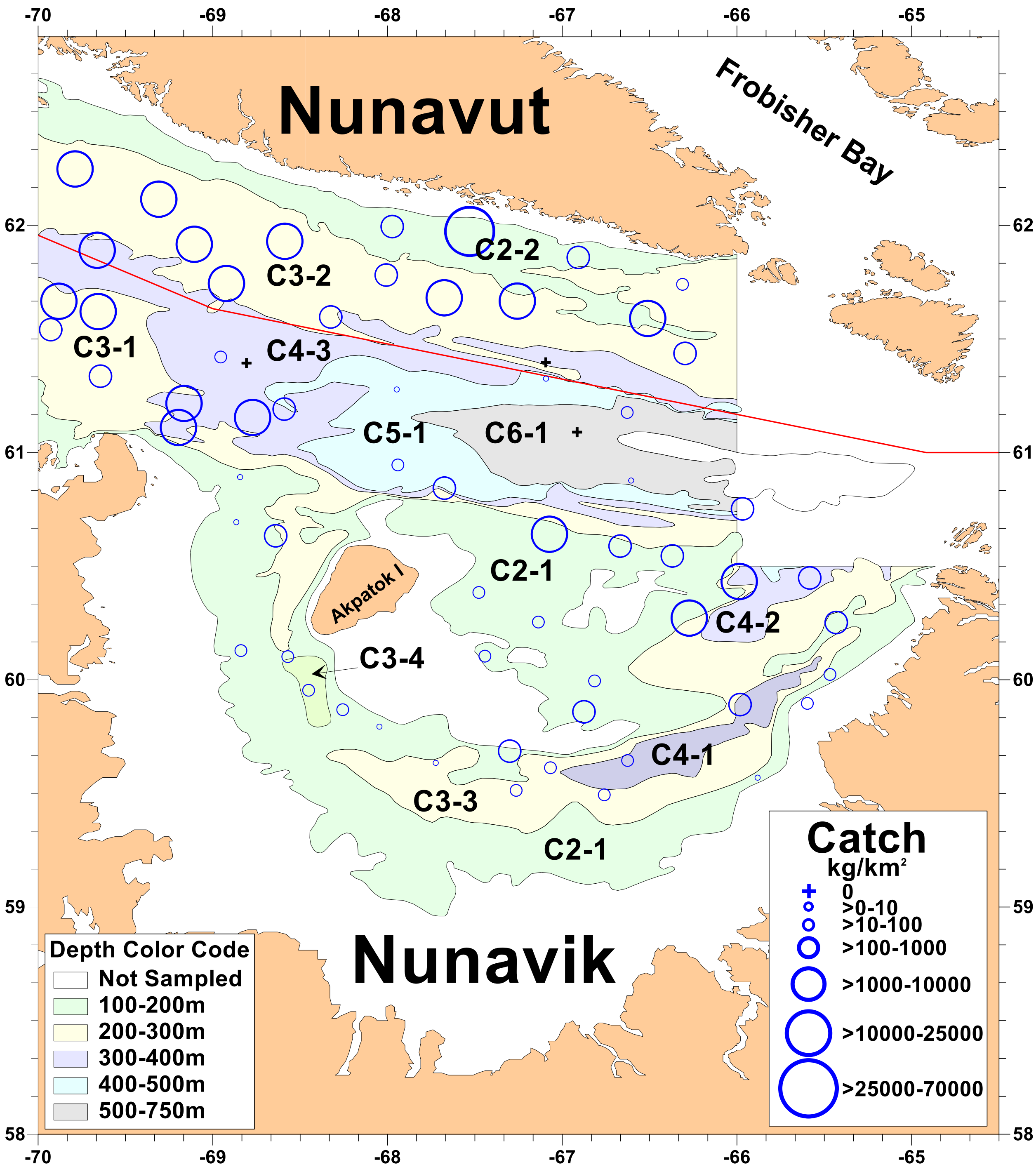

Figure 43. Standardized Pandalus montagui *catch from the 2015 Western Assessment Zone survey area overlying the depth contours and strata of the survey area.*

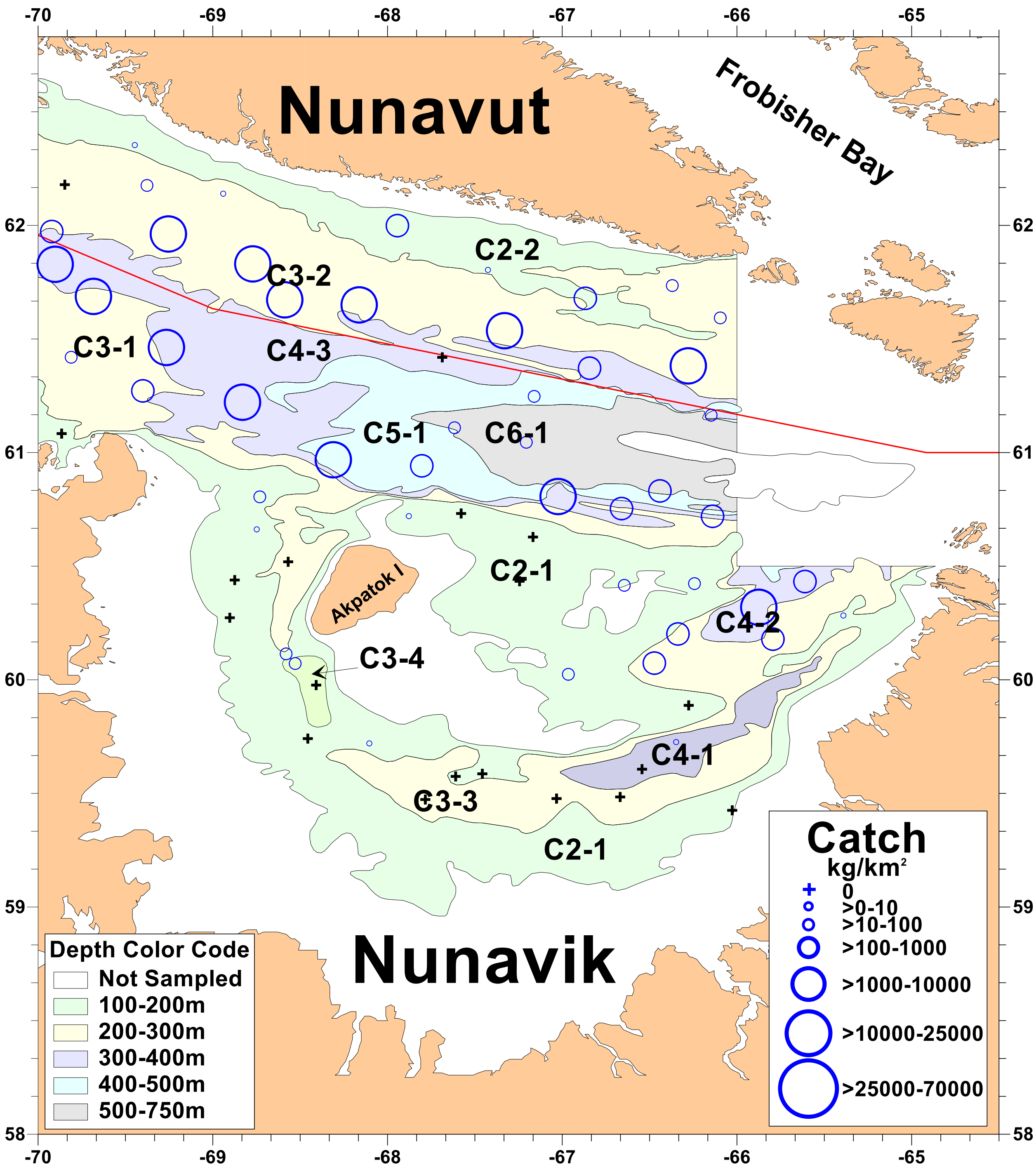

Figure 44. Standardized Pandalus montagui *catch from the 2016 Western Assessment Zone survey area overlying the depth contours and strata of the survey area.*

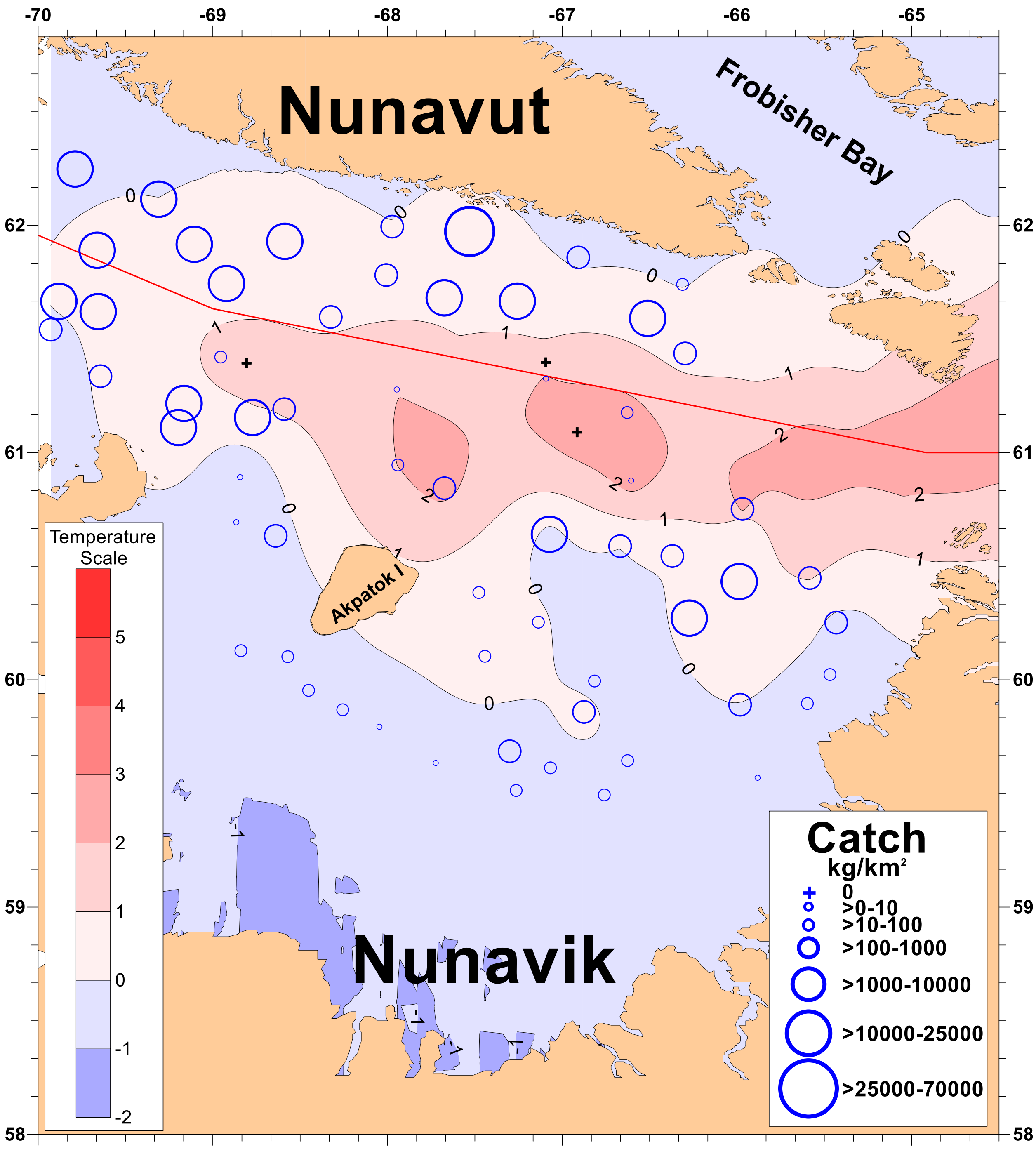

Figure 45. 2015 standardized Pandalus montagui *catch from the Western Assessment Zone overlying mean bottom temperature contours observed in the survey area.*

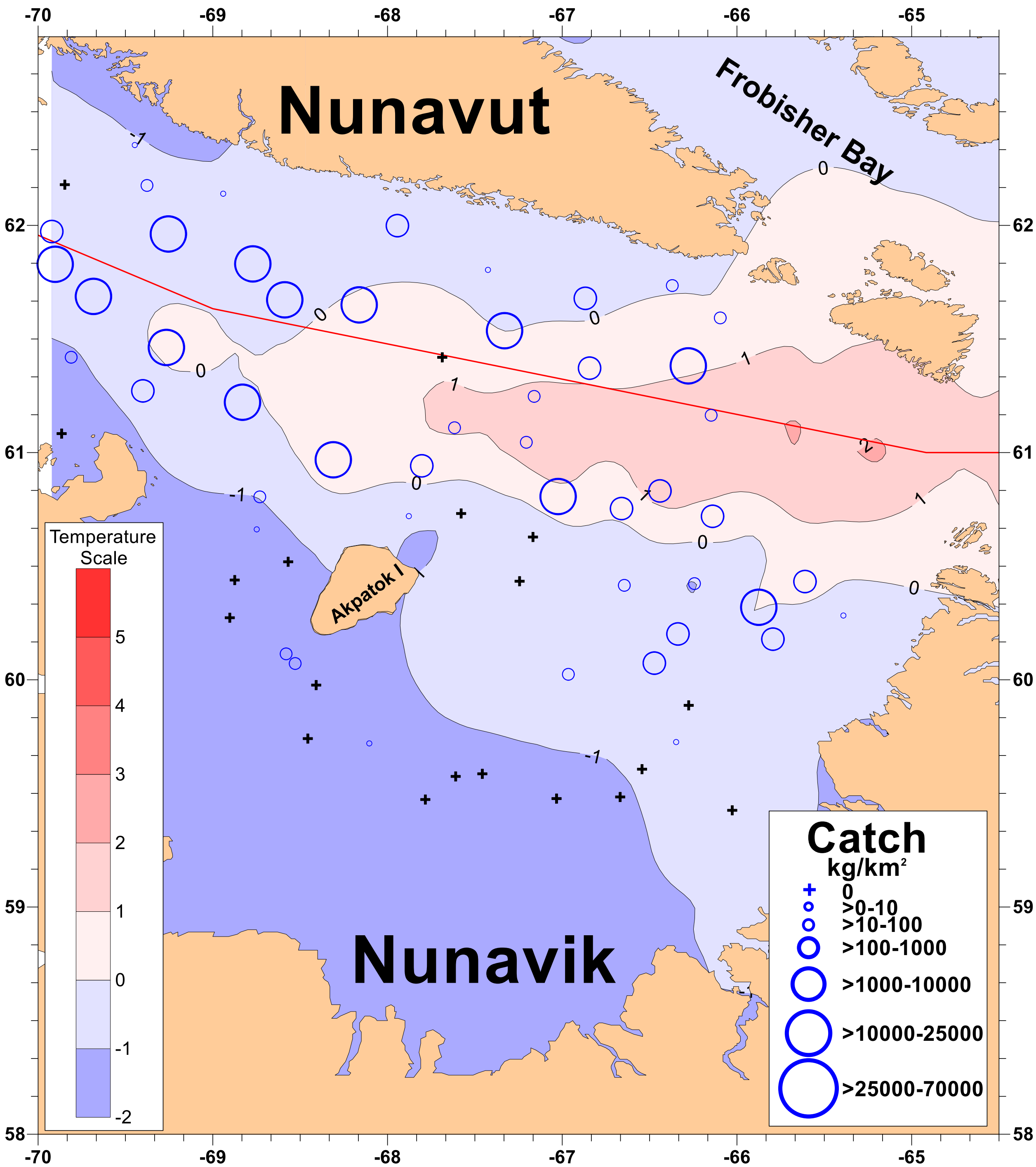

Figure 46. 2016 standardized Pandalus montagui *catch from the Western Assessment Zone overlying mean bottom temperature contours observed in the survey area.*

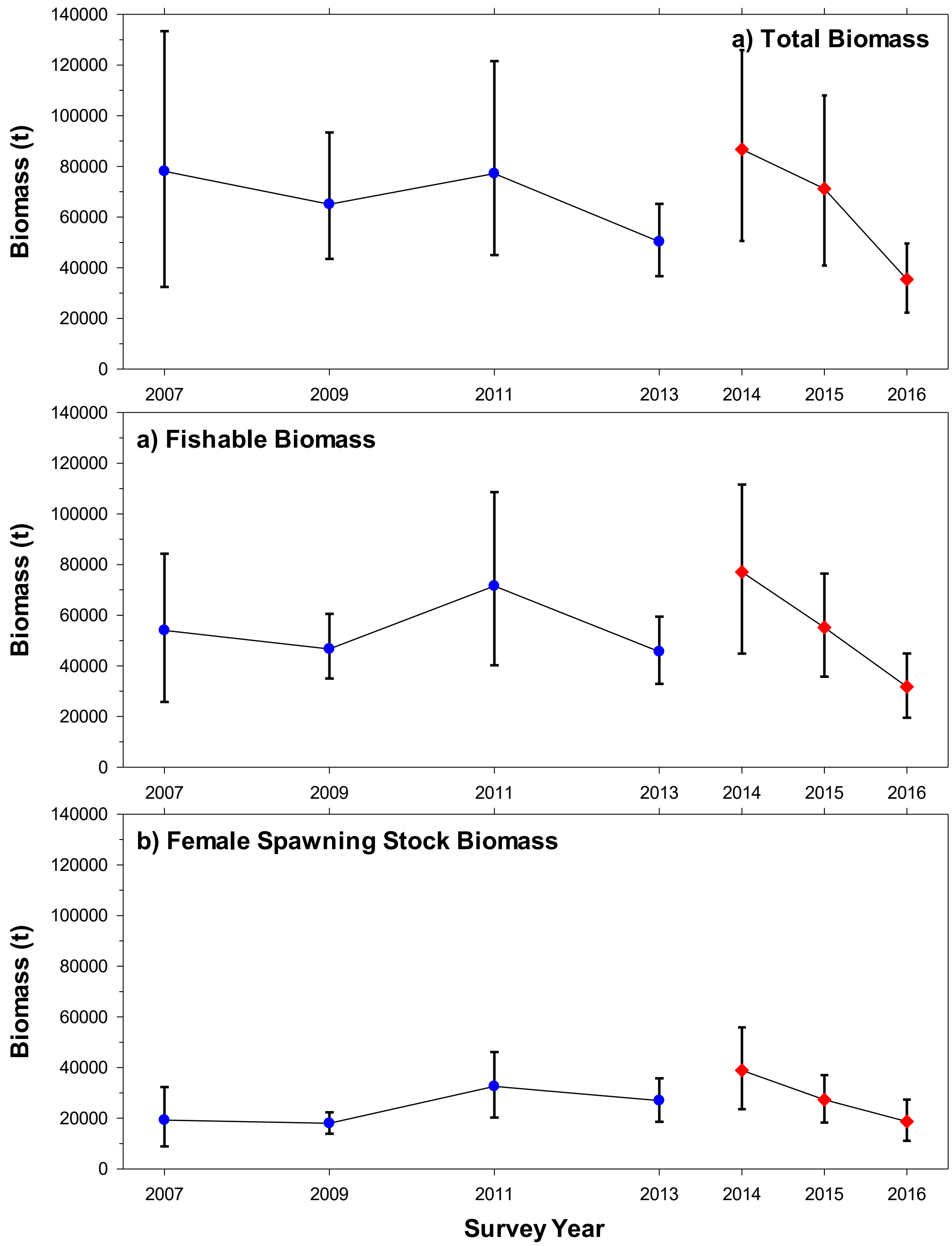

Figure 47. Western Assessment Zone Pandalus montagui*, a) total, b) fishable biomass and c) female spawning stock biomass indices. Included are four years of DFO/Cosmos surveys (blue circles), and the 2014 DFO-NSRF /Campelen survey (red diamond) which represents the start of a new time series. Error bars are 95% confidence ranges.*

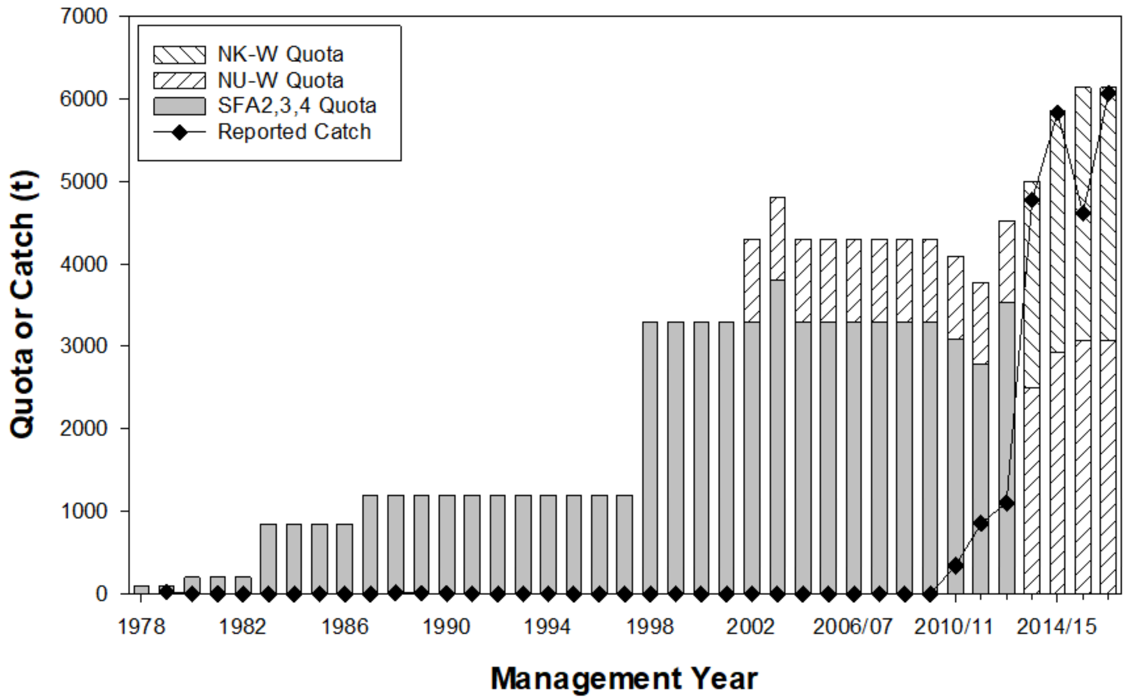

Figure 48. The Western Assessment Zone Pandalus montagui *TAC and catch recorded in the Canadian Atlantic Quota Report (CAQR). Catch based on CAQR as of February 2, 2017.*

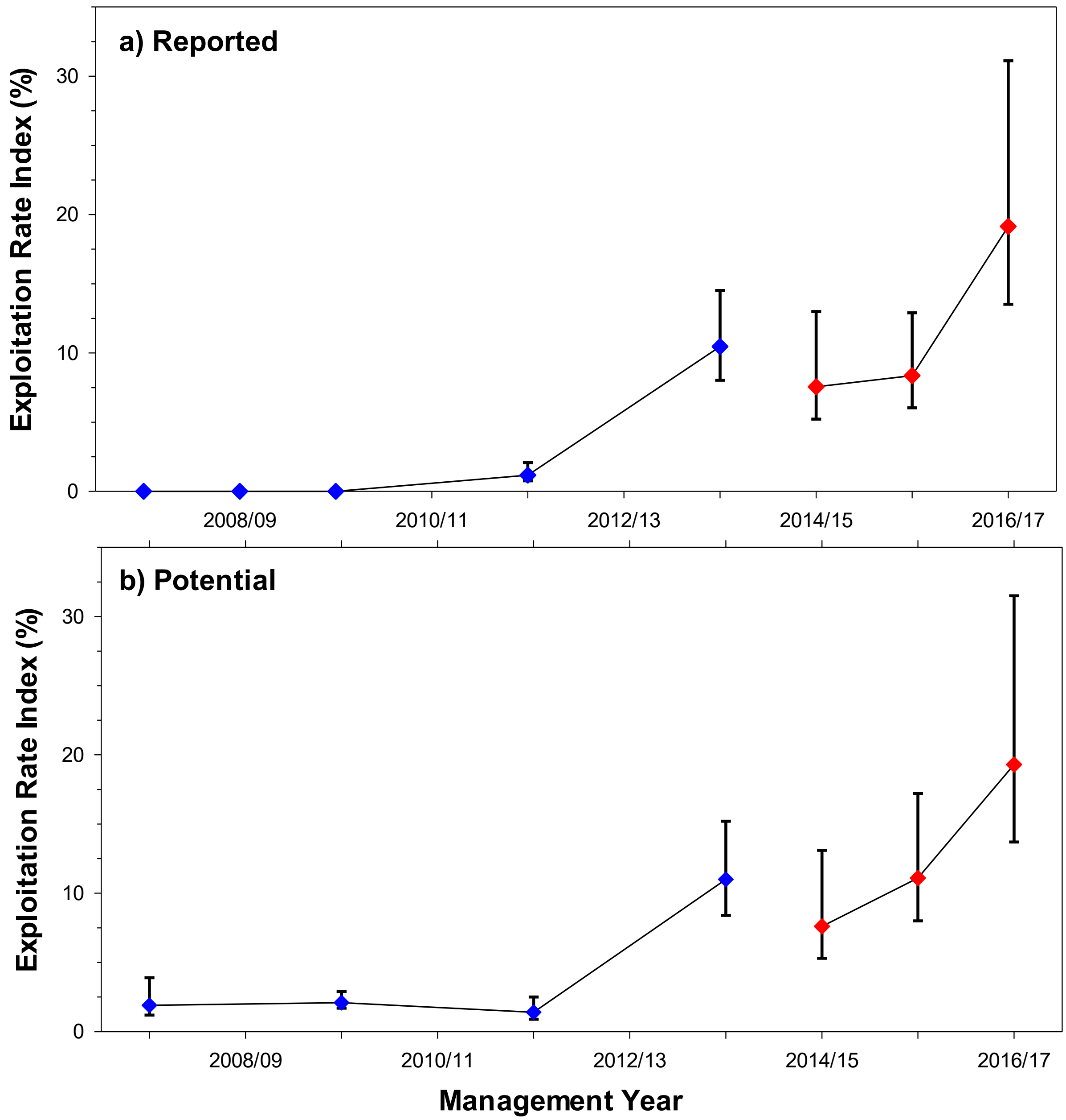

Figure 49. The a) reported and b) potential Western Assessment Zone Pandalus montagui *exploitation rate index. The DFO/Cosmos survey (blue diamonds) is not directly comparable with the 2014 survey (red diamond) conducted by the DFO-NSRF /Campelen. 2014 represents the start of a new time series. Error bars represent 95% confidence range.*